THIS PUBLICATION IS DEVOTED TO THE 25TH ANNIVERSARY OF THE NORTH CASPIAN PROJECT

UDC 502.51(035.3)
BBC 20.1
E40

Approved for publication by the Scientific and Technical Council of the Kazakhstan Agency of Applied Ecology (KAPE STC)

E40 Environmental Monitoring of the North-East Caspian Sea during Development of NCOC N.V. Oil Fields in the Period 2006-2016. – Almaty: NCOC N.V., KAPE, 2018 - 400p.

ISBN 978-601-332-146-2

The Monograph contains materials based on the results of environmental monitoring conducted by Agip KCO / NCOC N.V. during development of oil fields in Kazakhstan part of the North Caspian Sea. This second edition summarizes the monitoring materials for the period 2006-2016.

The presented results of environmental monitoring allow tracing the impact from operations on the biodiversity and the environment of the North-East Caspian Sea during development of the offshore oil fields. The Monograph materials present the results of the analysis of changes in the components of marine biota (plankton, benthos, ichthyofauna, etc.), as well as changes occurring in the abiotic environment (atmospheric air, sea water, bottom sediments, etc.). The Monograph is illustrated with maps, photographs and graphs.

The Monograph is intended for specialists in ecology, environmental protection, geography, hydrochemistry, hydrobiology and others, as well as for specialists in the oil and gas industry, and students of higher institutions.

ISBN 978-601-332-146-2

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North Caspian Operating Company N.V.

Environmental Monitoring of the North-East Caspian Sea during Development of NCOC N.V. Oil Fields in the Period 2006-2016

2018

Дизайн и печать выполнены в Казахстане

Bruno Jardin, Managing Director, NCOC N.V.

The 25th anniversary of the North Caspian Project will see NCOC N.V. publish the second monograph titled "ENVIRONMENTAL MONITORING OF THE NORTH-EAST CASPIAN SEA DURING DEVELOPMENT OF NCOC N.V. OIL FIELDS IN THE PERIOD 2006-2016".

The North Caspian Project is the first large-scale project to develop offshore oil and gas fields in Kazakhstan. Kashagan with its 35 billion barrels of oil in place stands out among them as it is the largest hydrocarbon discovery of the past four decades worldwide. It is unique in terms of the project's technological challenges, specifically its safe and efficient development.

It is known that the North Caspian Sea is a sensitive environmental zone with rich and unique flora and fauna. Without practical steps to preserve the Caspian marine environment that are grounded on state-of-the-art national and global environmental standards, the unique ecosystem could be impacted. In addition to hydrocarbon production, we as the Project Operator and our international partners have made it a priority to minimize environmental impacts of oil production. Therefore, we carry out systematic onshore and offshore environmental monitoring surveys, control the quality of air, water and bottom sediments, as well as the state of plankton, benthos, fish, birds and seals on a regular basis.

While implementing the North Caspian Project, we continuously take care to preserve the Northern Caspian environment and comply with the highest environmental standards.

The North Caspian Consortium invests annually billions of tenge to deliver the Environmental Protection Plan. In 2016 only, 5.5 billion tenge were spent for environmental protection measures and in 2017 – 4.8 billion tenge. And in 2017, over 955 million tenge were earmarked for environmental monitoring and surveys.

We hope that the readers will find it interesting to learn from the Monograph about the Company's environmental agenda in the North Caspian Sea as well as the findings of comprehensive marine environmental surveys from 2006 to 2016.

Yermek Marabayev,
Health, Safety, Security
& Environment Director, NCOC N.V.

I would like to present you a monograph summarizing the results of the multiyear environmental monitoring surveys conducted by the North Caspian Consortium in the area of offshore operations.

25 years ago, at the dawn of their activities in this region of Kazakhstan, the Consortium specialists were well aware of how significant and unique it is for the Republic of Kazakhstan. Therefore, preservation of the sea natural resources, its flora and fauna became one of our priorities. In pursuance of this objective we have been developing and successfully rolling out a number of programs on preservation of biodiversity, regulatory and environmental compliance monitoring. The programs provide for observations over the seawater and marine biota quality, special birds monitoring surveys. A dedicated package of surveys over of the population and status of the Caspian seals, the only representative of mammals, has been put in place. All observations are now conducted by lead experts from research and development organizations of the Republic of Kazakhstan.

The Monograph covers the outcome of the 2006 through 2016 monitoring surveys. This period encompasses the most critical milestones of the Consortium production activities. Above all, it is about completion of the construction and installation phase and start-up of Kashagan Field - one of the largest in the Caspian region in terms hydrocarbon reserves. In the meantime, the Kalamkas-Sea exploration was ongoing. The environmental status of the Aktote and Kairan suspended wells on artificial islands could not be left unattended, either.

The offshore petroleum operations expansion prompted the monitoring enhancement. The number of the monitoring stations, the survey scope and frequency increased ten-fold in this period. In recent years, the number of stations grew up to 300 vs. 200 per season, and the surveys started to be conducted all-year round.

The Monograph emphasizes the scale and extent of the surveys, and the data processing will secure a true assessment of the environmental impact by the Consortium activities. I am pleased to share that the presented facts demonstrate the recorded changes in the biotic and abiotic parameters are within the limits of natural fluctuations and the ecosystem maintains the structural and functional integrity and natural self-recovery capacity.

It gives us certainty that operations in the Caspian Sea might as well be conducted in strict compliance with all the environmental requirements and laws of the Republic of Kazakhstan and international standards.

Baltabai Kuanyshev,
Corporate Services Director,
NCOC N.V.

The backbone of the environmental policy pursued by the North Caspian Venture in the course of the oil and gas field development is the environmental protection priority. Since 1993 the Venture has delivered up to 200 comprehensive environmental surveys of the North Caspian Sea in the areas of its petroleum operations. Their findings prove that ongoing petroleum operations do not cause any pollution due to rigorous and stringent compliance with environmental requirements of the Republic of Kazakhstan and constant monitoring of the environment.

The efficient system of industrial and environmental safety has been put in place at all Company's facilities. All the waste from offshore facilities is taken onshore, disposed and recycled with the help of the cutting-edge equipment. It fully meets all international standards and the Company has pursued this practice from the very inception of its operations in the Caspian Sea. Regular large-scale environmental surveys, including satellite observations, are carried out annually and during all seasons. The Company's licensed areas are covered with an extensive network of industrial environmental monitoring. Moreover, all offshore facilities have a multi-level system to detect and prevent emergencies.

The North Caspian Venture is implementing an array of measures to preserve the biodiversity of the Caspian Sea, specifically, we fund the artificial sturgeon reproduction with subsequent release of fingerlings into their habitat in order to replenish sturgeon populations.

Years of surveys helped us to accumulate extensive environmental data and present assessments of the current state of the North Caspian ecosystem. NCOC N.V. showcases its openness through regular community updates about the state of the North-East Caspian environment. The findings of multi-year environmental surveys are published in scientific papers and reports and presented at community meetings and gatherings.

In 2014, Monograph "ENVIRONMENTAL MONITORING OF THE NORTH-EAST CASPIAN SEA DURING DEVELOPMENT OF OIL FIELDS, 1993-2006" was published, which was the first major compilation of environmental surveys for 1993-2006.

This year, on the eve of the 25th anniversary of the North Caspian project, we present the second Monograph "ENVIRONMENTAL MONITORING OF THE NORTH-EAST CASPIAN SEA DURING DEVELOPMENT OF NCOC N.V. OIL FIELDS IN THE PERIOD 2006-2016". The survey outcomes are construed given the natural environmental changes and all human impacts on the marine environment which enhances the credibility of key findings, estimates and recommendations of researchers who were involved in the environmental monitoring of the North-East Caspian Sea.

We hope that this publication will once again demonstrate our openness and that it is possible to perform petroleum operations without adverse impacts on the marine environment and in stringent compliance with Kazakhstan's and international environmental standards.

TABLE OF CONTENT

Specific terms, definitions and abbreviations

Term / Abbreviation	Explanation / Definition
CEM	Compliance environmental monitoring carried out by the Company offshore. Before 2013, it was called the "Environmental Baseline and Monitoring Surveys". In 2013-2016 – "Offshore Environmental Surveys" or "Impact Monitoring" carried out in accordance with the "Rules for the Organization and Performance of Industrial Environmental Monitoring during Petroleum Operations in the Kazakhstan Sector of the Caspian Sea"
CEP	Caspian Environmental Program
CISS	Caspian International Seal Survey
Company	Company appointed as the Operator under the PSA: - Agip KCO - North Caspian Production Operations Company B.V. (NCPOC) - North Caspian Operating Company N.V. (NCOC N. V.)
Contregulators	Water distribution systems
D Island	Operational and processing complex. Artificial structures (islands, pipe racks and modules) with producing wells and process facilities for primary oil and gas preparation. Support staff lives and works on D island.
EPC2, EPC3, EPC4, Island A	Artificial offshore islands where petroleum is produced. They are unmanned islands.
Environmental monitoring	Abbreviated name of an environmental monitoring survey at sea, carried out by Company in 2006-2016
GPS	Global Positioning System GPS navigation system, satellite global positioning system.
HC	Hydrocarbons
Intra-Field Pipelines	Designed for transportation of petroleum fluid from islands A and EPC-2,3,4 onto Island D
IUCN	International Union for Conservation of Nature and Natural Resources.
Kalamkas	Abbreviated name of the offshore Kalamkas-sea field
KAPE	Kazakhstan Agency of Applied Ecology LLC
KEP	KazEcoProject LLC
KSCS	Kazakhstan Sector of the Caspian Sea
LQBs	Living Quarter Barges
MPC	Maximum permissible concentration
N-E Caspian Sea	North-East Caspian Sea
Offshore complex	A complex of offshore facilities for Phase I of Kashagan Development Experimental Program. It includes islands A, D, EPC2, EPC3, EPC4 and Oil field pipeline . Technological processes at the offshore facilities include preliminary oil preparation, separation, drying and crude gas re-injection.

Термин / Аббревиатура	Объяснение / Определение
PAH	Polyaromatic hydrocarbons
Production Sharing Agreement (PSA)	Production Sharing Agreement in respect of the North Caspian Sea dated November 18, 1997, as amended and supplemented.
RoK	Republic of Kazakhstan
SMRU	Sea Mammal Research Unit Located in the Scottish Oceanographic Institute.
SPLASH	Seal tagging, which shows its location, depth and temperature of water
SPOT	Small Position Only Tag (a small tag showing only the location of seal)
SRDL	Satellite Relay Data Logger
SRV	Scientific Research Vessel
Track	Track/line of a recorded seal movement
Transect	A line (section, route) showing coordinates at bends
Oil Fiel Pipeline	Designed for: a) pumping raw hydrocarbons from Kashagan offshore facilities to the Onshore Processing Facility - Bolashak OPF; b) pumping fuel gas from the OPF to the offshore facilities.
UCIBIF	Ural-Caspian Interregional Basin Inspection of Fisheries
WC	Wildlife Computers Company
Zhaiyk	The Ural River
Zhem	The Emba River

INTRODUCTION

The Caspian Sea is the largest inland endorheic water body in the world possessing all properties of a sea. The Caspian Sea is characterized with unpredictable long-term cyclic level changes.

The Caspian Sea is a unique water body, its hydrocarbon resources and biological resources are unparalleled in the world. The Caspian Sea is unique also for its preserved relic flora and fauna until present days, including sturgeons and seals. The Caspian Sea is a major migration route and a habitat for waterfowl and semi-aquatic birds. Geographic location, natural-climatic and hydrological conditions provide the Caspian Sea with the status of an important centre of biodiversity conservation.

Today, the Caspian Sea ecosystem is subject to changes driven by natural factors and human activity. In compliance with the RoK environmental legislation NCOC N.V. conducts regular monitoring of marine ecosystem elements to timely identify potential negative trends and take appropriate environmental protection measures and conserve species diversity.

Biodiversity conservation is a set of measures intended for wildlife study and conservation. Surveys(monitoring) of the current condition of flora and fauna of Kazakhstan sector of the Caspian Sea could be considered as the priority measure. One of the elements of such surveysis environmental monitoring in NCOC N.V. oil fields development areas. Such monitoring is also performed for the following purposes:

- Compliance with requirements of international conventions for environmental and biodiversity protection
- Compliance with regulatory requirements of the Republic of Kazakhstan
- Timely identification and assessment of negative changes of marine environment condition in oil fields development areas
- Assessment of potential environmental consequences of production operations impact on the environment
- Efficiency of environmental protection measures implemented, justification of environmental protection activities
- Information support for the development and implementation of measures intended to prevent potential negative changes in the environment condition in oil field areas.

Offshore environmental monitoring surveys (environmental monitoring) in the North-East Caspian Sea started at the earliest stages of oil production activities (seismic acquisition, geophysical surveys, construction activities, etc.) and continued up to date during all subsequent stages of the Company oil field's development. The Monograph shows how monitoring area has been expanded, the number of stations and frequency increased over the last years.

INTEGRATED MARINE ENVIRONMENTAL SURVEYS COMPLETED IN 2006-2016 IN CONTRACT AND OTHER AREAS OF NORTH-EAST (NE) CASPIAN SEA OBJECTIVELY SHOW CURRENT STATUS AND RECORD CHANGES IN BIOTIC AND ABIOTIC COMPONENTS OF MARINE ENVIRONMENT.

NCOC N.V. publication of the compendium of articles (Compendium) Monitoring of North-East Caspian Sea Environment during oil fields' development in 2014 gave a start to a series of publications that will reflect monitoring stages during hydrocarbon resources development in Kazakhstan sector of the Caspian Sea.
The Compendium summarized the data of

multi-year monitoring (1993-2006) of offshore oil field development operations impact on the NE Caspian biodiversity and environment. The Compendium published in 2014 was in demand among ecology and environmental protection specialists, fish and oil and gas industry workers for handling research and applied tasks, environmental expert review, regulation of oil production in water areas, raising environmental responsibility of the oil and gas industry. During the presentation of the Compendium in Atyrau and Mangystau oblasts, the public requested regular publications of environmental condition data at various stages of petroleum operations, implying that books shall be published at least every 10 years.

This Monograph continues the publication of information with environmental monitoring results that began in 2014. The Monograph contains monitoring results over the period of 2006-2016. The review of environmental monitoring information over these years is of particular interest, as artificial island construction, pipelines construction, drilling operations, and equipment delivery and commissioning at Kashagan offshore facilities were conducted during that period. Therefore, Monograph articles are of interest because they cover a period of vast range of offshore activities preceding Kashagan oil production.

NCOC N.V. PLANS TO CONTINUE PUBLICATIONS ON ENVIRONMENTAL STATUS IN FUTURE AT THE FOLLOWING STAGES OF HYDROCARBONS COMMERCIAL PRODUCTION. FURTHER EDITIONS OF SIMILAR MONOGRAPHS WILL COVER MARINE ENVIRONMENT STATUS DURING INTENSE COMMERCIAL PRODUCTION OF KASHAGAN OIL AND DEVELOPMENT OF OTHER OFFSHORE FIELDS.

Over 11 years (2006-2016) of surveys under Environmental Monitoring Programs, they were attended by dozens of scientists and specialists from different countries. The main scope of work was completed by leading Kazakhstan companies providing consultancy and research services in the area of ecology and nature use: Caspiecology Environmental Services LLP, Kazakhstan Agency of Applied Ecology (KAPE) LLC, Kazekoproject (KEP) LLP and others.

The surveysinvolved leading experts from a range of Kazakhstan organization and research centres of the National Academy of Sciences, including: institutes of nuclear physics, zoology, microbiology and virology, hydrobiology and ecology and other, as well as Republican research and production centres (Fishery, Kazgidromet RSE, etc.); specialized laboratories Ekogidrohimgeo, Nuclear Physics Institute of the MES of the RoK, NAC LLP, Institute of Hydrogeology and Geoecology named after U. M. Akhmedsafin, ALOOS LLP, Kazekoanaliz LLP, Chemical Analytics Centre Testing Laboratory of KAPE LLP in Aktau, Hydrobiological Laboratory of KAPE LLP, RSPRC Kazekologiya, SSE Research Institute for Biology and Biotechnology Matters of RSE KazNU named after Al-Farabi, EkoServis-S LLP and others. Specialists of these organizations not just participated in monitoring surveys, but also provided valuable expert and consultancy support.

Substantial contribution to surveys was also made by foreign ecological companies, such as: AGRA (Canada), Arthur D. Little (USA and Great Britain), ERM (Great Britain), Ecology & Environment (USA), ERT (Scotland), Institute of Zoology (London, Great Britain), Institute of Integrative and Comparative Biology (University of Leeds, Great Britain), Scottish Museum of Natural History (Stockholm, Sweden) and others.

This Monograph was prepared by specialists of NCOC N.V., KAPE LLC and leading experts of the Republic of Kazakhstan. The authors of Monograph chapters are:

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Cartography works and database preparation for the Monograph were completed by A. Chernov and I. Sapozhnikova, specialists of Well Logging Team of KAPE LLP.

Kashagan ice properties and sea level information was presented by: Technical Department, Geoinformation Department, Hydrometeorology and Ice Facts Department of NCOC N.V.: A. Yergalieyv, B. Kim, A. Abuova, M. Kadranov.

Specialists from various countries participated in marine environmental surveys of 2006-2016. However, mainly they were specialists from Kazakhstan companies, including the authors of this Monograph articles.

Marine environmental studies:

N. Abdrimova, K. Alishev, B. Altureyev, T. Altybayev, O. Bednenko, B. Bektemisov, V. Berezovskiy, T. Bisekenov, N. Boos, Ye. Gorbanev, A. Zulkashev, R. Imanaliyev, D. Ismagulov, Ye. Ismukhanov, A. Kalashnikov, S. Kaldayev, S. Kaldybayev, Zh. Kaliyev, Sh. Kanagatova, B. Kapanov, F. Karpov, Ye. Kasymbekov, F. Klimov, V. Korotkov, N. Kostyurin, O. Kochnev, A. Kuat, A. Kulagin, T. Kuttybayev, T. Lebedev, A. Levin, A. Linnik, V. Mischenko, Ye. Murova, I. Orlova, A. Pavlenko, N. Popov, S. Rizaidinov, M. Saraliyev, A. Semyanistov, S. Sergeyev, K. Stepanov, I. Stogov, L. Stogova, S. Surgutskaya, L. Ulyanova, L. Khvan, A. Shakirov et al.

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THE MONOGRAPH IS PUBLISHED IN THE YEAR OF 25TH ANNIVERSARY OF THE NORTH CASPIAN PROJECT, THEREFORE, IT IS PARTICULARLY IMPORTANT TO NOTE THAT ALL OFFSHORE PRODUCTION OPERATIONS DURING THESE YEARS HAVE BEEN ACCOMPANIED WITH ENVIRONMENTAL MONITORING. MONITORING RESULTS ENABLED NOT JUST OBSERVING THE ONGOING CHANGES IN MARINE ENVIRONMENT, BUT ALSO JUSTIFYING THE PRIORITY AREAS FOR REQUIRED ENVIRONMENTAL PROTECTION MEASURES UNDER PLANNED ACTIVITIES.

Obtained results of environmental monitoring also allowed to complete a comprehensive assessment of marine environment and biodiversity in quite extensive water area of the North-East Caspian Sea that are presented in this Monograph and in the previous edition.

Monitoring study participants and Monograph authors express their sincere appreciation to NCOC N.V. management for a long-term, considered and justified performance of comprehensive environmental studies. Our special thanks are to the specialists who made a major contribution to arranging offshore monitoring surveysfor many years – Paul Barrett, Giovanni Rivas, Gulsim Mutysheva, Sagiden Yerbulekov and Vladimir Terentyev.

1. BACKGROUND OF OPERATIONAL ACTIVITIES AND DEVELOPMENT OF ENVIRONMENTAL MONITORING SURVEYS BY THE COMPANY

1.1 Overview of NCOC N.V. Petroleum Operations in the North-East Caspian Sea

Future prospects of oil and gas potential in the North Caspian Sea were predicted by Soviet geologists. However, the country with an extensive history of oil industry development had never performed any offshore operations. The turning point occurred some years later with independence status of the Republic of Kazakhstan when on February 13, 1993 the Governmental Resolution On Development and Hydrocarbon Production in Kazakhstan Part of the Caspian Sea was signed and envisaged inter alia establishment of a specialized national company "KazakhstanCaspyShelf".

By June 9, 1993 for the first time in Kazakhstan, the concept of the first phase of the National Program for Development of Kazakhstan Sector of the Caspian Sea was developed and approved.

In total, 50 companies expressed their intention to participate in the "Major Caspian Project". Only several companies could be selected who had experience of work in the statuss similar to the Caspian Sea and were ready to accept the financial requirements of Kazakhstan. Attracted investments were intended for establishing the "KazakhstanCaspiShelf" company and funding the initial offshore operations.

On May 23, 1993, the Consortium's configuration was defined. The following six companies were competing for membership: Mobil (USA), alliance of Statoil (Norway) and British Petroleum (Great Britain), Shell (UK / Netherlands), Agip (Italy), British Gas (Great Britain) and Total (France). KazakhstanCaspiShelf was proposed as the seventh equal partner in the project.

ON 3 DECEMBER, 1993 THE AGREEMENT ON ESTABLISHMENT OF INTERNATIONAL CONSORTIUM FOR GEOLOGICAL EXPLORATION IN KAZAKHSTAN SHELF OF THE CASPIAN SEA WAS SIGNED WITH APPOINTMENT

of "KazakhstanCaspiShelf" as the Operator, as well as the Agreement on three-year geological surveys of the oil potential in the region. This date was a starting point of the partnership with major international oil companies under the project for development of Kazakhstan shelf.

The program of geophysical survey in the shelf, carried out by the Consortium in 1994–1997, became one of the largest in the world in terms of 2D seismic scope (26,180 line kilometers in the area of 100,000 square kilometers) and at the same time the shortest in terms of survey duration.

Based on the results of surveys conducted in the Caspian Sea, for the first time a map of geological exploration blocks was developed with identification of huge prospects in the northern part of the sea, such as Kashagan, Kairan and Aktote (Figure1.1). Kashagan alone was much larger than the well-known Tengiz field.

It is worth noting that much attention was paid to environment protection during implementation of such major project in the Caspian Sea. As

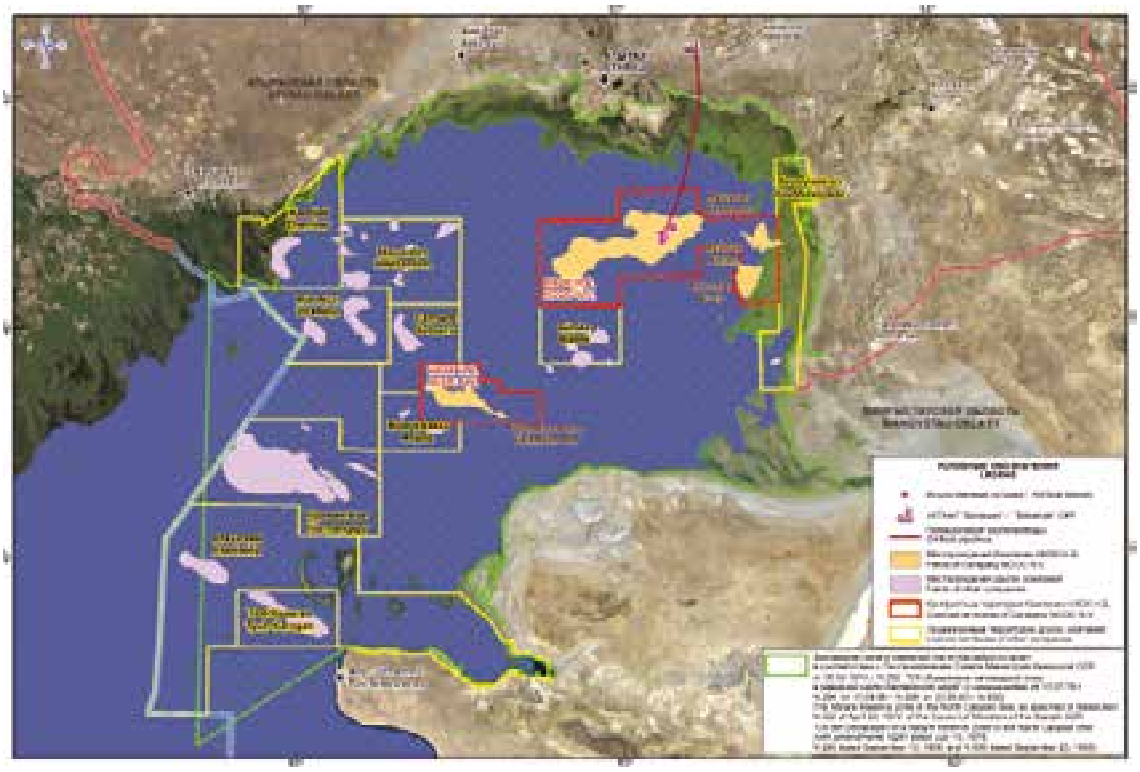


Figure 1.1 NCOC N.V. Contract Areas

instructed by Nursultan Nazarbayev, the President of the Republic of Kazakhstan, the Consortium completed a special environmental program and developed for the first time a comprehensive picture of the Caspian Sea environmental state. Large-scale activities were carried out in the framework of the preliminary environmental survey to determine environment baseline status and to assess the environmental impact from seismic operations. In addition, a complete map of the environmental sensitivity of the Kazakhstan sector of the sea was developed. Such surveys in the Caspian Sea had never been conducted before in such volume and at such technical and methodological level. The results of this work would become later a powerful information basis for the local scientific organizations and investors who would come to the shelf.

After completion of the seismic survey, the members of the Consortium started negotiations on the Production Sharing Agreement in respect of the North Caspian Sea (NCPSA), which was signed with the Government of the Republic of Kazakhstan on November 18, 1997. This Agreement regulated the Consortium's activities aimed at performance of exploration drilling and commercial production of Caspian oil.

IN SEPTEMBER 1998, THE INTERNATIONAL CONSORTIUM "OFFSHORE KAZAKHSTAN INTERNATIONAL OPERATING COMPANY" (OKIOC), WAS ESTABLISHED FOR EXPLORATION AND PRODUCTION OF HYDROCARBONS IN THE NCPSA AREA AND DEVELOPMENT OF OFFSHORE FIELDS IN KAZAKHSTAN.

This Consortium included all participants of the previous International Consortium on the Caspian shelf exploration. However, in October, 1998 the National Company "Kazakhoil" representing Kazakhstan in OKIOC Consortium, sold its share to two new participants — Inpex, a Japanese company, and Phillips Petroleum, an American company. "KazakhstanCaspyShelf" JSC became a part of "Kazahoil" structure in charge of geological and geophysical surveys.

NCOC B.V. and NCPOC, undertaking the duties of NCPSA Project Operator.

At present, North Caspian Operating Company N.V. (NCOC N.V.) acts as the Project Operator on behalf of the Consortium including seven oil and gas companies with a relevant participating interest in the Project.

In 2001, Agip Caspian Sea B.V., a subsidiary of the Italian ENI, was selected as a single operator for the North Caspian Project. After that OKIOC Consortium was renamed into Agip KCO. Appraisal of oil and gas reserves was completed in June 2002 and thereafter, the Consortium announced about commercial reserves of hydrocarbons.

In spring 2005, the national company "KazMunaiGas" bought 8.33% share in the North Caspian project from the British BG Group, out of 16.67% offered for sale, and again became a member of the International Consortium. In November 2008, the share of "KazMunaiGas" NC was increased to 16.81%. Thus, the national oil company became one of the five major shareholders of the Project.

On January 22, 2009, the new operating company North Caspian Operating Company B.V. was established (NCOC B.V.), which took over the duties of a single operator for NCPSA, formerly performed by Agip KCO. As the operator, NCOC B.V. defined and managed a common strategy, carried out planning and coordination, organized geological, geophysical and other surveys, and interacted with stakeholders.

In late 2013, ConocoPhilips exited the project, selling its share to KazMunaiGas. Later, KazMunaiGas re-assigned this share to CNPC.

In June 2015, the process of restructuring of the operational model of the North Caspian Project was completed by merging North Caspian Operating Company N.V. (NCOC N.V.) with North Caspian Operating Company B.V. (NCOC B.V.) and the NC Production Operating Company B.V. (NCPOC). As a result of reorganization, NCOC N.V. became the universal legal successor of

The discovery of oil at Kashagan

After the PSA signing, active preparations began for exploration drilling on the shelf, when the Consortium had to conduct important work. The Consortium's shareholders fully realized the concerns of the Government and the public regarding the environmental component of the project on the Caspian Sea shelf. This was the first project of petroleum operations in the protected zone of the North Caspian Sea, which required special attention to environmental issues.

In accordance with the Environmental Code of the Republic of Kazakhstan and the Law of the Republic of Kazakhstan On Specially Protected Areas, the aquatic area of the eastern part of the North Caspian Sea is included in the state preserved area (Figure1.1), therefore, any activities related to petroleum operations are allowed here only in accordance with special environmental requirements. Thus, in addition to environmental surveys in the areas of intended operations, OKIOC specialists, in cooperation with the Kazakhstan experts, conducted an Environmental Impact Assessment prior to drilling, received all necessary permits and licenses for the work. The Consortium established a professional environmental team and had in place a clear system for monitoring organizing and reporting.

FOR THE FIRST TIME IN KAZAKHSTAN THE NORTH CASPIAN CONSORTIUM INTRODUCED THE PRACTICE OF PUBLIC HEARINGS, CONSULTATIONS WITH THE PUBLIC AND SCIENTISTS OF THE ROK,

where the local community was informed about the technical aspects of the project and, most importantly, was involved into open discussions of environmental issues.

When choosing drilling and waste management methods, a number of features of the North-East Caspian ecosystem was taken into account, i.e. shallow water, ice cover in winter, ice movements and ice hummocks around offshore artificial structures, reservoir pressure and high concentration of hydrogen sulfide in the pre-salt hydrocarbon reservoirs.

Sunkar drilling barge had been modified. This submersible barge was chosen as the best option for drilling in shallow waters, because the average water depth in the area of Kashagan East is about 3.5-4.0 meters. Preparations to exploration drilling in the North Caspian coincided with an epochal event for Kazakhstan - celebration of the 100th anniversary of commercial oil production. The country, which had such a long history in development of its oil and gas industry, produced already 27 million tons of oil per year, taking the 26th place in the world in terms of production volumes.

On August 12, 1999, in accordance with the PSA, signed by the Republic of Kazakhstan with partners in the North Caspian Project, the OKIOC Consortium spudded the first exploration well Kashagan East-1. It was the first wildcat well in the entire Kazakhstan shelf of the Caspian Sea.

The oil-bearing reservoir was discovered in the Paleozoic carbonates at the depth below 4,000 meters. The daily flowrate of the well was 600 cubic meters of oil and 200 thousand cubic meters of gas. This was the first victory of oilmen in Kazakhstan shelf of the Caspian Sea.

ON JULY 4, 2000, NURSULTAN NAZARBAYEV, THE PRESIDENT OF KAZAKHSTAN AND OKIOC CONSORTIUM MANAGEMENT ANNOUNCED OFFICIALLY THE DISCOVERY OF HYDROCARBONS IN THE FIRST EXPLORATION WELL IN KASHAGAN EAST AREA.

In mid-September 2000, Sunkar drilling barge was relocated to the Kashagan West prospect and in April 2001, the exploration well had discovered oil in this prospect with the daily flowrate of 530 cubic meters of oil and 230,000 cubic meters of gas.
In September 2002, successful drilling results were announced at Kalamkas-sea field. Later in August 2003, oil was found at Kashagan South-West, and in September 2003 - at Aktote and Kairan fields. Thereafter, the RoK Governmental Resolution as of 25 February, 2004 approved the Development Plan envisaging a phased field development.

Current Status

The Contract Area of NCPSA includes Kashagan, Aktote, Kairan, Kalamkas-sea fields (Figure1.1).

Kashagan is the largest field in the Consortium's Contract Area. Original oil in place is estimated at 35 billion barrels of oil. Kashagan reservoir is located at the depth of about 4 kilometers below the sea bed and is under high reservoir pressure up to 800 bars. Kashagan crude oil is light, with a high content of hydrogen sulphide. The field covers the area of about 75x45 km and is located at about 80 km distance from Atyrau. Currently, the development of Kashagan field is at the Experimental Development Phase (Phase 1).

Kashagan field includes onshore and offshore facilities. The onshore facilities are Bolashak onshore processing facilities (OPF) and a railway complex (EWRP). The following offshore facilities have been constructed and currently are in operation: hubs on D Island, A Island, the early

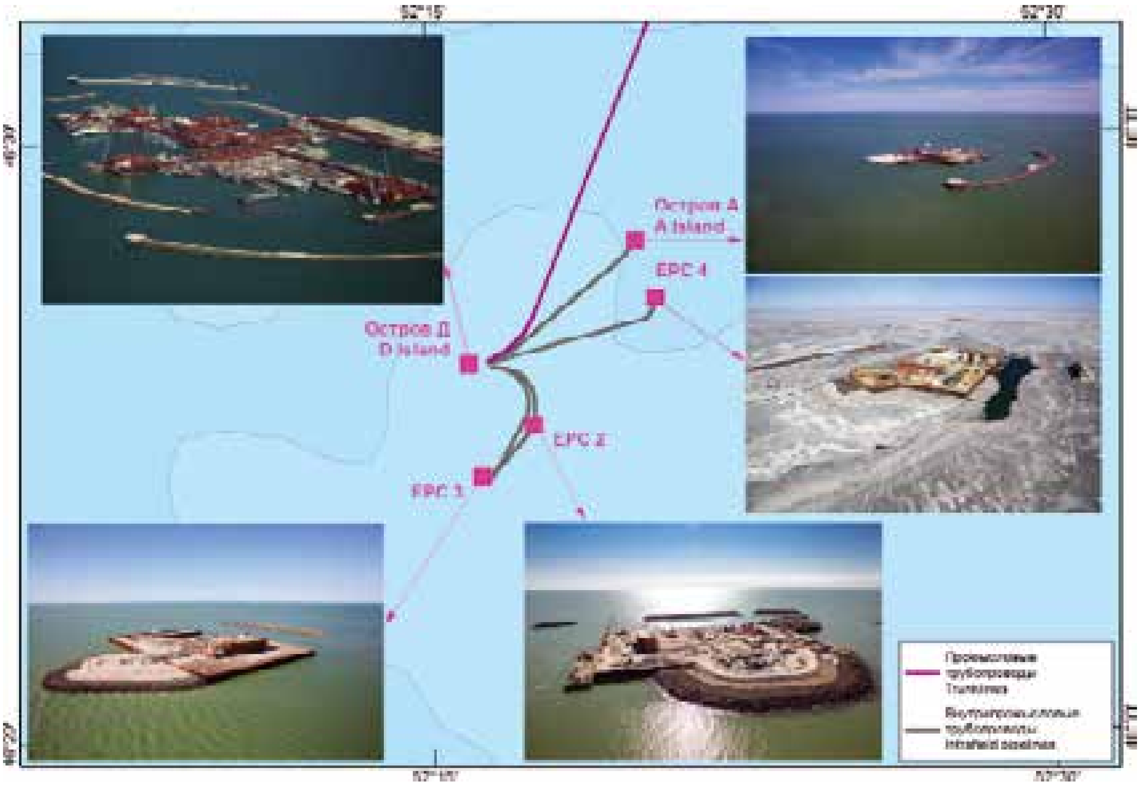


Figure 1.2. Kashagan Field. Offshore Artificial Islands

production centers — EPC 2, 3 and 4 islands (Figure 1.2). The following facilities have also been constructed for the further phases of Kashagan development: islands DC 2, 4, 5. The Oil field pipeline (offshore section of about 70 km long) were laid to connect the offshore and onshore facilities (another name - the northern pipeline route) and intrafield pipelines.

On September 11, 2013, production started at Kashagan field. However, due to the gas leakage in the gas pipeline, the production was suspended from October 2013. Based on the results of intelligent pigging, external inspection and laboratory surveys, the Contracting Companies made a decision about complete replacement of oil and gas Oil field pipeline between Bolashak OPF and offshore facilities in 2015–2016. The Company completed the replacement of Oil field pipeline in 2016, and continued its commissioning program.

ON 1 NOVEMBER, 2016, THE PRODUCTION AT KASHAGAN REACHED THE COMMERCIAL LEVEL OF OVER 75,000 BARRELS OF OIL PER DAY. ON 7 DECEMBER, 2016 AN OFFICIAL PRESENTATION RELATED TO THE START OF PRODUCTION AT KASHAGAN WAS HELD IN ATYRAU WITH PARTICIPATION OF THE HEAD OF THE STATE.

"The current level of oil exceeds 200,000 barrels per day. Following the optimized process of raw gas re-injection into the reservoir it is planned to increase oil production to 370,000 barrels per day. The expected volume of production in the current year is set at 8 million tons of oil and 4.5 billion cubic meters of gas, "said Makhambet Dosmukhambetov, the First Vice-Minister of Energy in Kazakhstan, at the 25th Kazakhstan International Oil and Gas Conference, KIOGE 2017, in Almaty.

Thus, the period 2006-2016 under review in this Monograph included the following types of activities at Kashagan: construction of islands, drilling operations, pipelines laying, commissioning, vessels and construction barges movement. Commercial oil production at Kashagan field started in late 2016.

Kairan. The area is about 1,000 km^2. Recoverable oil reserves — 35,761 thousand tons, dissolved gas – 33,536 million m^3.

Aktote. Pre-salt gas condensate field. The area is 390 km^2. The deposits cover the area of 13x6 km and are about 1,000 m thick. The recoverable condensate reserves are 76,918.5 thousand tons; dry gas is 169,486.3 million m^3.

Artificial islands have been constructed in the field. In 2006-2007 the exploration drilling was conducted and appraisal had been completed.

Kalamkas-sea field (hereafter Kalamkas) is located at 130 km distance to the south-west of Kashagan field. The area of Kalamkas field is 1,274 km2. The nearest land is Bozashi peninsula.

In 2002, the first well (Kalamkas-1) was drilled and it discovered a new field. Oil free flow and gas free flow to the surface were obtained from the Jurassic deposits. 14 hydrocarbon bearing formations were identified in the Middle Jurassic. Additional surveys of the field confirmed the commercial potential of the Middle Jurassic deposits as a result of additional wells drilling. (2005-2009):

In 2008, based on development of western area only, Kalamkas field was declared as "potentially profitable". The conducted analysis showed that the oil of Kalamkas field does not contain any hydrogen sulphide. Oil reserves of C1 + C2 category approved by the State Commission for Mineral Resources Reserves of the Republic of Kazakhstan: original oil in place -284.5 million tons, recoverable - 67.5 million tons.

Overview of the Republic of Kazakhstan Legislation Related to Performance of Monitoring in Kazakhstan Sector of the Caspian Sea

1.2

Environmental legislation contains a wide range of legal, economic and organizational regulatory measures aimed at protecting the environment and rational use of natural resources. Monitoring of the nature environment is of particular importance in such measures and mechanisms.

The main regulatory legal acts establishing the requirements to monitoring conducted by nature users, prior to the issue of the Environmental Code of the Republic of Kazakhstan in 2007 included the following documents:

— Law of the Republic of Kazakhstan No. 160-I of July 15, 1997 "On Environmental Protection" (expired in 2007)

— Law of the Republic of Kazakhstan No. 302-II of March 11, 2002 "On Atmospheric Air Protection" (expired in 2007)

— Law of the Republic of Kazakhstan No. 361-II of December 4, 2002, "On Sanitary and Epidemiological Welfare of the Population" (expired in 2009)

— Law of the Republic of Kazakhstan No. 2350 of June 28, 1995 "On Oil" (expired in 2010)

— Order of the Minister of Natural Resources and Environmental Protection of the Republic of Kazakhstan No. 50-p On Approval of the "Rules for Organization of Production Control in the Field of Environmental Protection" of 11 March, 2001 (expired in 2010)

— Rules for implementation of industrial environmental control, approved by the order of the Minister of Environmental Protection of the Republic of Kazakhstan No. 272-p of 22.09.05, (expired in 2010)

— Order of the Acting Minister of Environmental Protection of the Republic of Kazakhstan No. 258-p "On Approval of the Standard

Regulations on Industrial environmental control" as of 3 August, 2006 (expired in 2007)

- Standard rules for conducting industrial monitoring (approved by Order of MEP No. 45-p of 02.02.06, expired in 2007).

Since 2007, monitoring observations (surveys) have been carried out in accordance with the requirements of the Environmental Code of the Republic of Kazakhstan.

It should be noted that there are no definitions of "*industrial environmental control*" and "*industrial monitoring*" in the current *Environmental Code*. Therefore, these concepts shall be interpreted according to the current regulatory legal acts, namely the "Rules for organization and implementation of industrial environmental monitoring during the petroleum operations in Kazakhstan sector of the Caspian Sea" (Orders of the Minister of Energy of the Republic of Kazakhstan of 2012, 2014) and state standard ST RK 2036 -2010 "Protection of nature. Emissions. Guidelines for atmospheric pollution control":

- Industrial environmental control: a system of measures implemented by a nature user to monitor the state of the environment and its changes under the impact of economic and other activities, verification of implementation of plans and activities related to protection and improvement of the environment, reproduction and rational use of natural resources, compliance with environmental legislation, environmental quality standards and environmental requirements, including industrial monitoring, recording, reporting, documenting the results, as well as measures to eliminate the identified non-conformities in environment protection.

- Industrial monitoring: experimental (based on measurements) and/or indirect (based on calculations, if direct measurements are unavailable) assessment of certain parameters of the industrial process, physical and chemical factors of impact on the environment and environmental state changes as a result of economic or other activities.

- Industrial environmental monitoring - a complex of environmental observations of environmental state under the impact of industrial operations, arranged by a nature user in the zone exposed to environmental impact.

Currently, according to Chapter 14 "Industrial environmental control" of Environmental Code:

- Individuals and entities persons engaged in a special nature use are obliged to carry out industrial environmental control (IEC). IEC is conducted by a nature user on the basis of IEC program developed by the nature user.

- Industrial monitoring is a part of IEC.

In addition, Article 132 of the Environmental Code of the Republic of Kazakhstan stipulates that operational monitoring, monitoring of environmental emissions, and impact monitoring shall be conducted within the framework of industrial environmental control.

Impact monitoring is included in the program of industrial environmental control in cases when it is necessary to monitor compliance with the environmental legislation of the Republic of Kazakhstan and environmental quality standards. At the same time, impact monitoring is mandatory in the following cases:

- When activities of the nature user affect sensitive ecosystems and population's health state

- At the stage of processing facilities commissioning

- After emergency environmental emissions.

Moreover, the Environmental Code stipulates that industrial environmental monitoring shall be carried out by industrial or independent laboratories accredited in accordance with the procedure established by legislation of the Republic of Kazakhstan in the field of technical regulation.

According to Article 133 of the Environmental Code of the Republic of Kazakhstan, a nature user shall provide regular reports about results of industrial environmental control, in accordance with the requirements established by the authorized body in the field of environmental protection.

Such requirements are provided in "Requirements to reporting on the industrial environmental control results" (Order No. 16-p dated 14 February, 2013 of the Minister of Environmental Protection of the Republic of Kazakhstan, as amended).

Also, taking into account that petroleum operations in Kazakhstan sector of the Caspian Sea can have a potential impact on the sensitive ecosystems of the North Caspian Sea, a nature user shall comply with the below requirements.

Chapter 38 "Environmental requirements to economic and other activities in the state preserved area in the North Caspian Sea" of the Environmental Code of the Republic of Kazakhstan obligates the subsoil user to conduct annual industrial environmental monitoring (by climatic seasons) throughout the contract area, except for monitoring in winter when the sea is covered with ice.

If necessary, and as required by the authorized body in the field of environmental protection, the subsoil user shall perform additional environmental surveys.

The "Rules for the organization and implementation of industrial environmental monitoring during performance of petroleum operations in Kazakhstan sector of the Caspian Sea" in 2012 (expired in 2015) and effective Rules under the same name (approved by Order No. 132 of the Minister of Energy of the Republic of Kazakhstan on 20 November, 2014) envisage organization and performance of industrial environmental monitoring (IEM) during petroleum operations in the KSCS.

These Rules provide for a list of components and environmental parameters to be identified during IEM performance which includes:

- rhydro-meteorological parameters
- physical factors
- atmospheric air
- sea water
- bottom sediments
- benthos
- phytoplankton
- zooplankton
- aquatic vegetationь
- ichthyofauna
- avifauna
- seals

The Rules also obligate the nature users to develop an Environmental Pollution Monitoring Program.

According to IEM, nature users shall provide annual reports on impact monitoring results to the authorized body in the field of environmental protection.

If necessary, and as required by the authorized body in the field of environmental protection, the subsoil user shall conduct additional surveys of environmental state (Clause 5, Article 269 of the Environmental Code of the Republic of Kazakhstan).

The "Rules for organization and implementation of baseline environmental surveys during petroleum operations conducted in Kazakhstan sector of the Caspian Sea" (Order No. 131 dated 20 November, 2014 of the Minister of Energy of the Republic of Kazakhstan, as amended) are also relevant and they establish a procedure for performance of such surveys. At the same time, the concept of *baseline environmental surveys of marine environment* is defined as performance of special comprehensive surveys of the *initial state* of marine environment in the Contract Area of the subsurface user, including sections of linear facilities.

It should be noted that industrial monitoring data can be used to assess environmental state within the framework of the Unified State System for Monitoring of Environment and Nature Resources (Articles 132, 139 and 144 of the Environmental Code of the Republic of Kazakhstan).

The additional legal basis for environmental monitoring is a large package of regulatory legal documents, sanitary rules and hygienic standards, state standards, instructions and methodology documents, etc. specifying and detailing the specifics of monitoring. However, due to their large number and scope, they are not listed and analyzed in this overview.

Development of Environmental Monitoring Surveys by NCOC N.V. 1.3

NCOC N.V. has in place the Health, Safety and Environment Management System to manage the issues of environmental protection. Monitoring surveys are carried out in accordance with such system.

This Monograph discusses the results of the offshore industrial environmental monitoring, carried out by NCOC N.V. (hereinafter referred to as the Company) in the licensed areas of Kashagan, Aktote, Kairan and Kalamkas in 2006-2016. It should be noted that prior to 2013 the offshore IEM conducted by the Company was called the "Baseline and monitoring environmental surveys of the North Caspian Sea". Environmental monitoring of the Company also included surveys in the sea coastal area (avifauna).

The Company also performs onshore monitoring in the area of coastal infrastructure (onshore processing facilities (OPF), Bautino support base, etc.), the results of which were not included in this publication.

Summer 1993 can be considered as the starting point of offshore environmental monitoring, when the "KazakhstanCaspiShelf" Company initiated and conducted assessment of geophysical operations impact on marine biota. Scientists of Kazakhstan along with experts from the United States, Great Britain and Russia were involved in those surveys.

In 1993-1994, monitoring surveys were focused on certain locations. In 1995, for the first time large-scale baseline surveys in the north-eastern part of the Caspian Sea were conducted. In 1996, baseline surveys were taken in the north-eastern part of the Caspian Sea, as well as monitoring of geophysical survey and drilling operations. The blocks were surveyed only in October 1997: Kashagan East and South-West, Aktote, Kairan and Kalamkas. In 1997-1998, monitoring surveys were conducted at certain locations already in 2 seasons of the year.

Despite the operatorship change, the main network of environmental monitoring stations in Kashagan and survey methods in the early period of operations have not change significantly; moreover, the survey area and the number of monitoring stations have been expanded, taking into account the development of Aktote, Kairan, Kalamkas sites and selection of the Oil field pipeline route from Kashagan to onshore.

Figure 1.3 shows the maximum number of stations involved annually in spring and summer surveys.

Let's review in more details development of the monitoring system in 2006-2016, since discussion of monitoring results acquired during this period is the main objective of this Monograph.

Up to 2012, the Company had been carrying out two types of the offshore monitoring according to different Programs:

— Environmental baseline and monitoring surveys (EBMS) of the North Caspian Sea, carried out according to Article 25 of the PSA

— Industrial monitoring carried out according to Article 132 of the Environmental Code of the Republic of Kazakhstan.

Starting from 2013, the Company had been conducting the monitoring surveys according to Integrated Program of Industrial Environmental Control (IEC), complying with the requirements of Article 132 of the Environmental Code of Kazakhstan and the Rules for organization and implementation of industrial environmental monitoring during petroleum operations in

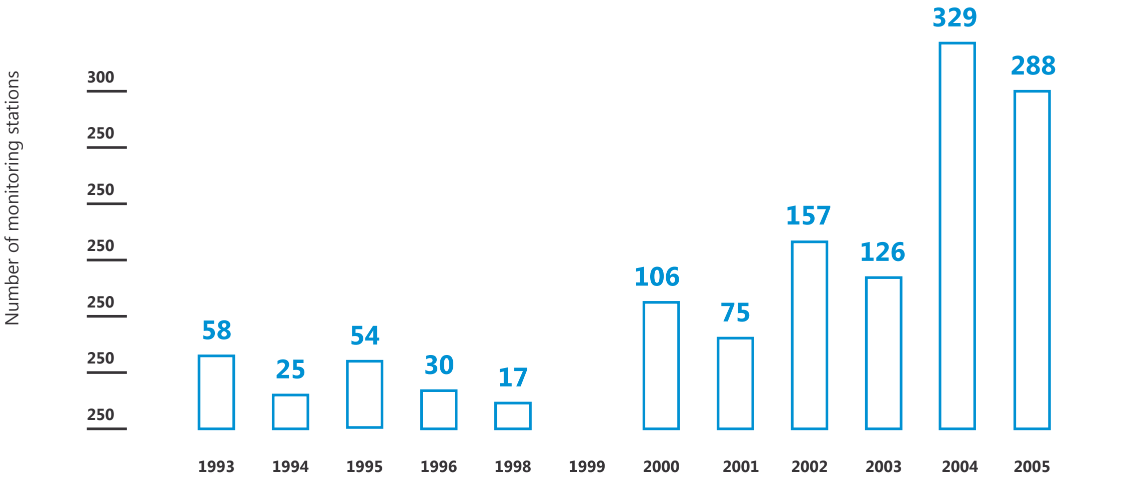


Figure 1.3 Development of Company's Monitoring Stations Network (Baseline and Offshore Environmental Surveys) before 2005.

Kazakhstan sector of the Caspian Sea (hereinafter the Rules ... 2012).

When the *Rules ..., 2012*, became effective the number of the offshore environmental monitoring stations had increased (Figure 1.4). Monitoring had been conducted in 4 climatic seasons. Before 2012, *environmental baseline and environmental monitoring surveys* had been performed annually in 2 climatic seasons: "spring and autumn" or "summer and autumn".

Also, the aquatic area for monitoring had been expanded. Maps and layouts of monitoring stations involved in surveys in 2006-2016 are shown in Figure 1.4 and Annex 1.

In 2013-2015 period, the number of industrial environmental monitoring stations near the offshore facilities of the Company (Figure 1.5) had increased as well as the frequency of monitoring and types of survey conducted according to the *Rules ..., 2012*. For example, the Company started

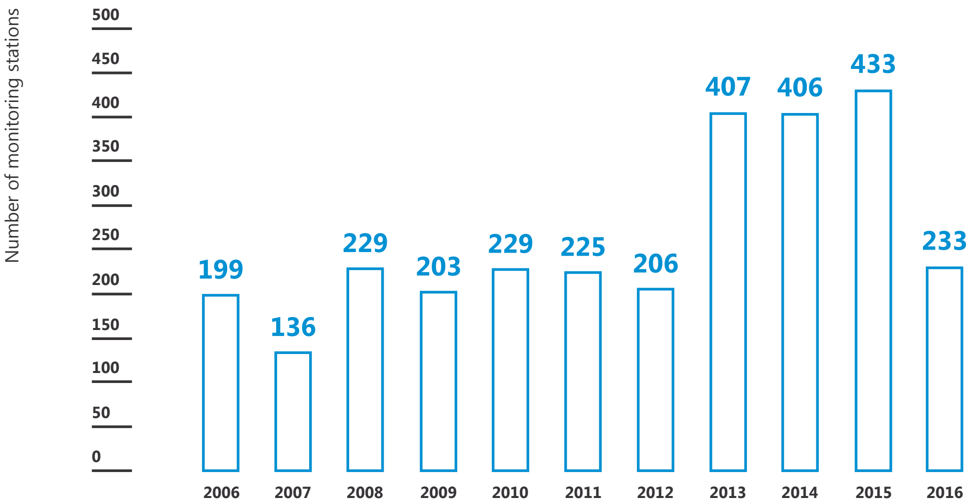


Figure 1.4 Maximum number of monitoring stations employed in one season during 2006-2016. 2006-2016 гг.

Table 1-1 The Number of measurements/samplings per season during Impact Monitoring in 2013-2015. Kashagan Field.

Monitoring sites, levels	Air	Sound (surface and sea bottom)	Water and plankton samples									Bottom sediments and benthos							Ichthyofauna		
			Biogens	HM	Phenols	Hydrocarbons	SSAS	COD	BOD5	Phytoplankton	Zooplankton	Granulometry	Redox potential (Eh)	TH	HM	Phenols	HC	Benthos*	Microbiology	Trawling	Nets	Aquatic vegetation
3 level	6	65	18	18	18	18	18	18	18	18	18	65	65	65	65	65	65	195	18	18	6	18
2 level	4	51	17	17	17	17	17	17	17	17	17	51	51	51	51	51	51	155	17	17	0	17
1 level																						
D Island	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
A Island	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
EPC 2	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
EPC 3	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
EPC 4	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
DC01	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
DC04	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
DC05	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
DC10	1	16	5	5	5	5	5	5	5	4	4	16	16	16	16	16	16	48	4	8	1	8
Total	**19**	**260**	**80**	**80**	**80**	**80**	**80**	**80**	**80**	**71**	**71**	**260**	**260**	**260**	**260**	**260**	**260**	**780**	**71**	**107**	**15**	**107**

Note: ** - 3 repeats at each station* regular air quality measurements and increased the number of seasons for IEM performance.

The Impact Monitoring Program for 2013 provided transfer to a three- level monitoring, according to the *Rules ..., 2012*. The planned (estimated) number of impact monitoring stations at all Company's offshore facilities was over 400 stations in each climatic season (except for winter) (Figure 1.5). However, the actual number of stations employed for surveys in each season could be less than those specified in the Programs for various reasons (small depths, prohibition of work for safety purposes, etc.).

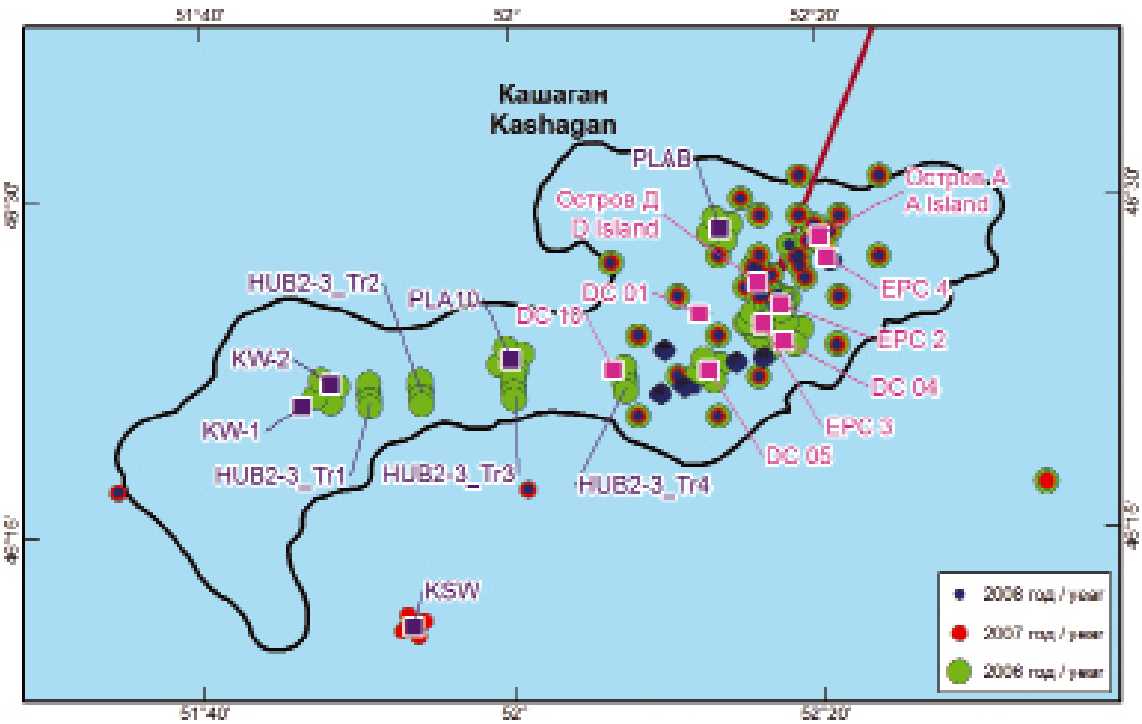
Thus, during the first planned start-up of Kashagan field (2013), the Impact Monitoring Program envisaged over 250 IEM stations (Table 1-1) [The Program of industrial environmental control in 2013. Book 2. Impact monitoring. NCOC / KAPE, 2012].

Rules for the organization and implementation of industrial environmental monitoring during petroleum operations in Kazakhstan sector of the Caspian Sea (2014) are applied to the Company's offshore facilities from 2016, however, in 2015 the Company performed its monitoring in accordance with *Industrial Environmental Control Program for 2015". Book 2. Impact Monitoring* prepared on the basis of the 2012 Rules.

The main difference between the system of monitoring stations in 2016 and 2013-2015 is the reduced number of stations and, consequently, the volume of water and bottom sediments samples, as well as other environmental components at each Company's location and the Oil field pipeline route (the northern pipeline route). Figure 1.5 and Figures in Annex 1 show the changes in stations network in different periods of the environmental monitoring.

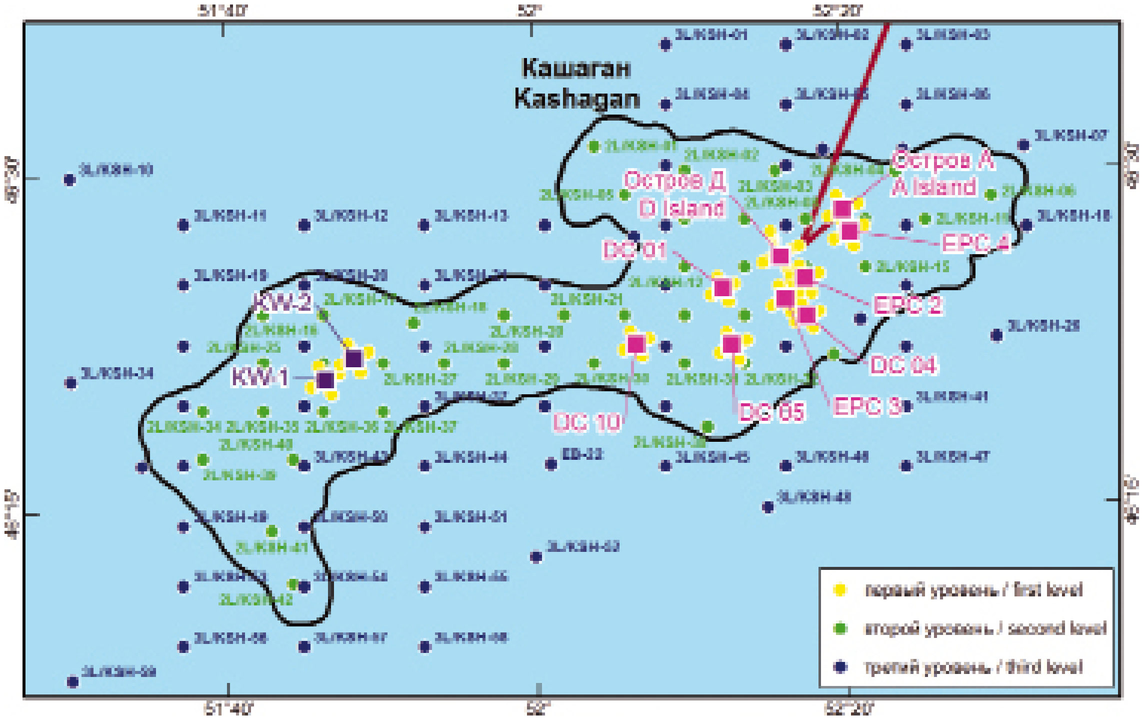
The difference between the 2016 Impact Monitoring Program [The industrial environmental control program for 2016, Book 2. Impact monitoring. NCOC / KAPE, 2015] and the 2015 Program are additional surveys of ichthyoplankton.

It can also be noted that the surveys in 2011 as compared to 2013-2016 period did not envisage monitoring of polyaromatic hydrocarbons in the water. At the same time, 2013-2016 Programs did not provide for monitoring of chlorophyll included previously in 2011- 2012 Programs.

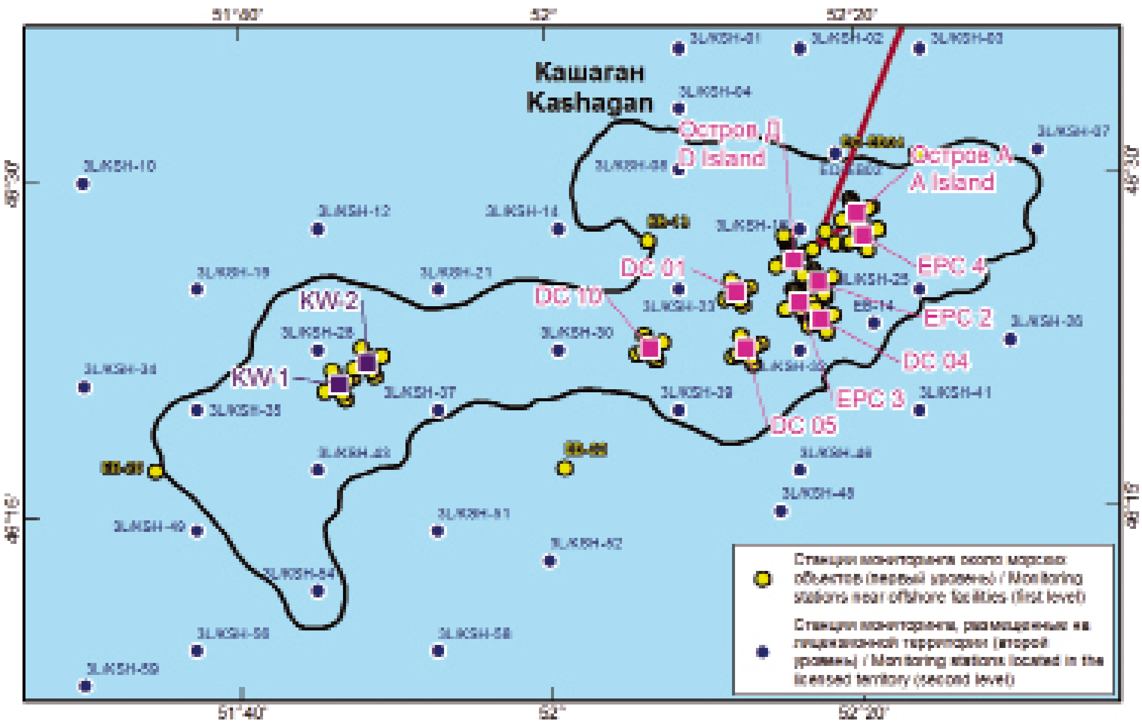


A - 2006-2008

Figure 1.5 Layouts of monitoring stations in different periods. Kashagan (A, B, C)



B - 2013-2015 - 1, 2 and 3 level monitoring stations



C - 2016 - two level monitoring stations

Figure 1.5 Layouts of monitoring stations in different periods. Kashagan (A, B, C)

2. ENVIRONMENTAL CONDITIONS OF THE NORTH-EAST CASPIAN SEA

NCOC N.V. Contract Areas (Kashagan, Kairan, Aktote, Kalamkas-Sea) are located in Kazakhstan sector of the north-eastern part of the North Caspian basin (Figure 1.1).

The described current state of the marine environment of the North Caspian Sea reflects the effects of the existing anthropogenic impact and long-term cyclic fluctuations of the sea level.

The environmental conditions of the North Caspian Sea have been analyzed on the basis of file materials, reference data, observations at RSE Kazhydromet hydro-meteorological stations, as well as NCOC N.V. data.

2.1 General Description of the Caspian Sea

The Caspian Sea is the largest inland water body in our planet that does not have a natural connection to the world's oceans, and, by a geographic definition, is the largest lake in the world (Figure 2.1). However, in terms of size, nature of fauna and hydrological conditions the water body retains features of a sea and, therefore, it is called the Caspian Sea [Panin, et al, 2005].

The length of the Caspian Sea in the meridional direction is about 1,200 km, the average width is 310 km with maximum 435 km, and minimum 196 km. The length of the coastline is over 7,000 km, including about 2,320 km within the territory of Kazakhstan. Given the current mark of minus 27 m BD the water basin area is 392.6 thousand km^2, and the catchment area is over 3.5 million km^2 of which 29.4% falls on the drainless area [Panin, et al, 2005].

More than 100 rivers and water streams flow into the sea. Their total inflow into the sea ranges from 205-215 to 450-460 km^3/year, with average about 300 km^3/year. This volume includes 80% of the Volga River and 5% of Zhayik (the Ural) River. About 10% of the inflow comes from the western coast rivers: Terek, Sulak, Samur, Kura and a number of other small rivers. The remaining 5% comes from the Iranian coast rivers. The eastern coast has no permanent water streams [Republic of Kazakhstan, Volume 1, 2006].

The sea has no tides, however, it is characterized by surge events.

Given specifics of the morphological structure and physical-geographical conditions, the Caspian Sea is divided into 3 parts: North, Middle and South Caspian. The boundary between the North and Middle Caspian runs conventionally along the Mangyshlak threshold from Tupkaragan Cape to the Kulalinskaya Bank and further to the Chechen Island. The boundary between the Middle and South Caspian runs along the Apsheron threshold — at the level of Zhiloy Island and Kuli Cape.

The northern part with the area of over 80 thousand km^2 is located in shallow water; the average depth is 5-6 m with the maximum depth of 15–20 m. The North Caspian Sea is an area of active mixing of river and sea waters. The middle part of the Caspian Sea is an isolated basin with the area of more than 138,000 km^2 with the average depth of 180-200 m, and the maximum depth of 788 m (the western coast of the Derbent depression). The southern part of the Caspian Sea with the area of about 150,000 km^2, has the average depth of about 345 m and the maximum depth of 1,025 m (the South Caspian hollow). The sea shelf is about 100 m deep on average.

The Kazakhstan sector of the Caspian Sea covers the eastern parts of the North and Middle Caspian Sea. By the administrative division, the coast is a part of Atyrau and Mangystau (Mangistau) regions of the Republic of Kazakhstan [Atlas of the Atyrau Region, 2014]. Its northeast (NE) part is located within the pre-Caspian depression, and the eastern part is represented by an elevated plateau of the Bozashchy (Buzachi), Tupkaragan (Tyub-Karagan) and Mangystau (Mangyshlak) Peninsulas (Figure 2.1).

5 independent states are located on the Caspian Sea coast. They all have well developed oil and gas industries and are extracting raw materials, both offshore and onshore. Due to the fact that pollutants can spread to a large enough water area, and because ichthyofauna, avifauna and seals migrate, the Caspian Sea environmental issues are relevant for all the Caspian countries. Any incidents, emissions and discharges of pollutants into the sea in one region can have a negative impact on the entire ecosystem of the Caspian Sea.

Figure 2.1 The Caspian Sea

The Caspian Sea shows intensive navigation activities. Development of navigation and oil and gas industry both offshore and onshore is likely to increase further, therefore, a number of pollution sources in the Caspian Sea will also increase.

Current Environmental Issues of the North Caspian Sea

The north-eastern part of the Caspian Sea, which is a national nature reserve zone (Environmental Code of the Republic of Kazakhstan, Art.256), has a number of environmental issues that are relevant to this region and that are not only caused by development of oil fields. Such environmental issues include:

- Control of the river inflow
- Long-term cyclic fluctuations of the sea level
- Chemical pollution of the sea (river inflow, sewage water from enterprises and settlements located on the coast, washing off pollutants from the coast with wind surges and long-term activities related to oil exploration and production)
- Invasion of alien organisms;
- Regular death of seals caused by various reasons including climatic changes
- Reduction of fish stock, including valuable fish species, caused by a number of factors: illegal fishing, increase of anthropogenic pollution, control of river inflow, sea level fluctuations.

Features of the North-East Caspian Sea Environment 2.2

Geology

North-eastern part of the Caspian Sea, including NCOC N.V. License Areas (Kashagan, Kalamkas-Sea, Kairan and Aktote fields) is located within two large elements: the ancient pre-caspian syneclize in the north and the epi-hercynian Turanian plate in the south. The approximate boundary between them (the marginal joint) runs from the Mertvy Kultuk sors to the avandelta of the Volga river.

The northern part of the Turanian plate in the shelf is represented by a series of small uplifts, altogether called as the Kulalinsky ridge, which transfers to the North Buzachinsky uplift in the east, extends sub-latitudinally and onshore. The structure of the Mesozoic-Cenozoic cover here is more stable. The cross section is predominantly fine and fine-grained: clays, siltstones, sands and sandstones, limestones, marls. The main pay zones in the pre-caspian syneclize are located below the salt at the depth of 3.5–7 km, whereas within the Turanian plate, such depths are 2–4 times less. The thickness of the Pliocene-Quaternary, predominantly terrigenous deposits, is characterized as a complex structure due to a frequent alteration of continental and marine conditions in the major part of the North Caspian Sea. Quaternary deposits are developed over the entire surface of the northern shelf, excluding small areas adjacent to the Tupkaragan Peninsula. The thickness of the Pleistocene does not exceed 100–200 m here. Novokaspiysk, Mangyshlak, Upper Khvalynskiy and Lower Khvalynskiy horizons were found in the Quaternary deposits in the North Caspian Sea. (The Caspian Sea, 1987, Mobil Report, 1993].

The Caspian Sea was formed as a result of the break-up of the secondary geosynclinal ocean — Eastern Paratethis [Caspian Sea, 1987]. Subsequent inversion of the shelf turned the Mangyshlak peninsula, the coasts of the Caucasus, Iran, and Turkmenia into land, and therefore, the Late Pliocene, Akchagylian and Apsheron transgressions belong to the isolated Caspian Sea (1.5–3 million years ago).

Significant fluctuations of the sea level and the related changes of the borders in the Caspian Sea basin occurred repeatedly in a quaternary geological period. The following transgressions were established: Baku (400–500 thousand years ago), Early Khazar (more than 250 thousand years ago), Late Khazar (90–130 thousand years ago), Early Khvalyn (35–65 thousand years ago), Late Khvalynian (10–20 thousand years ago) and Novocaspian, which had three peaks (8, 6, 2.5 thousand years ago). The range of sea-level fluctuations was significant. According to some reports [Caspian Sea, 1992] during the pre-Baku time period, the Caspian Sea level was lower than the current level by 120 m, and at the maximum of the early Khvalyn transgression, the level was higher than the current level by 75 m.

Lithological and stratigraphic description

THE DRILLED STRATIGRAPHIC CROSS SECTION OF KASHAGAN FIELD IS REPRESENTED BY SEDIMENTARY ROCKS RANGING FROM THE UPPER DEVONIAN TO THE NEOGENE.

Lower Permian evaporites (Kungurian stage) divide sedimentary deposits into two complexes: upper (post-salt) — Mesozoic-Cenozoic and lower (pre-salt) — Paleozoic.

The Upper Devonian deposits of the Frasnian (D_3fr) and Famennian (D_3fm) stages are composed of recrystallized, dense, partly dolomitized, organogenic limestones. The thickness of the sediments is 325–335 m.

The Carboniferous system is represented by an incomplete stratigraphic cross section consisting of Lower Carboniferous deposits (Turney, Visean, Serpukhovian stages) and lower middle Carboniferous (Bashkirian stage), carbonate composition, with the total thickness of about 750 m. The Lower Permian series is divided into the Artinskian pre-salt and Kungur salt layers. Sulphate-halogen rocks of the Kungur stage are represented by salt rock with layers of anhydrite, interbeds of argillites, siltstones, sandstones.

The post-salt structural layer is composed of terrigenous rocks of the Upper Permian, Triassic, Jurassic and Cretaceous ages with packs of carbonate rocks 20–70 m thick in the Upper Jurassic layers and 100–200 m in the Upper Cretaceous. The complex is intensively dislocated by the processes of salt diapirism.

Undifferentiated Permo-Triassic deposits are represented by brownish and red clay stone and argillites, sandstones and clay stones, as well as limestone layers. Their thickness is 230 m.

The Upper Triassic is represented by gray and gray-green siltstones with interlayers of sandy siltstone. The thickness of the sediments is about 160 m.

Jurassic deposits are represented by terrigenous and carbonate sediments of all three divisions and lie on the eroded surface of Triassic sediments. The thickness of the Jurassic deposits is 1,100 m. They are composed of interbedded sand, sandstone, siltstone, thin coal layers and clay stones. The sedimentary complex of the Cretaceous period is subdivided into Upper and Lower Cretaceous deposits. They are represented by layers of sand and clay with interlayers of limestone. The upper part of the Cretaceous rock is mostly composed by petrified clays, with limestones, marls, chalk and argillites located above. The total thickness of the sediments is 900–1,400 m.

Deposits of the Paleogene and Neogene systems are represented by limestones, interbedded sands, sandstones, siltstones and thin layers of gypsum. The thickness ranges from 95 to 180 m.

Quaternary deposits are represented by sandy, silty rocks of the Novocaspian layer, underlain by dense gypsum clays of greenish-gray color with spots of iron oxides. The latter are more likely to be of the Upper-Khvalynian age.

Seismicity

According to the seismic zoning map of the Atyrau region [Seismic zoning, 2003], the water basin where EP offshore facilities are located refers to the 5–point seismic zone based on MSK–64 scale.

Geomorphology of the Seabed

ACCORDING TO THE MORPHOMETRIC FEATURES, THE CASPIAN SEA IS A WELL-DEVELOPED SHELF ZONE IN THE NORTH.

Several types of underwater and predominantly accumulative plains are present in the North Caspian shelf. The following regularities can be noted in the shelf terrain of the North-East Caspian Sea: there is a gradual change of the sea plains (caused by the surge currents) from the coast to the plains formed by the surge and wave processes.

The north-eastern part of the Caspian Sea is a wide shelf zone with depths less than 20 m and is a continuation of the coastal plains of the pre-caspian depression. The seabed surface is characterized by a gentle slope to the south and a weak compartmentalization. The surface is characterized by a number of shallows, erosion-accumulative elements, hollows, furrows, developed during the Pliocene-Quaternary regression period by ancient river systems. Migratory sand banks are well noted at 0.5–3.0 m depth. The whole troughs system is oriented from north to south, showing that the shelf is a run off area confirmed by absence of a positive alleviation balance. Here, relicts of the ancient river network are widely developed — semi-buried valleys, sometimes even with preserved river terraces. Underwater continuation of the Zhayik riverbed is called the Ural Furrow with the maximum depth of 9–16 m, which became a lake basin in the regression periods. Convective seabed currents play a major part in the formation and reconstruction of the shallows network.

The terrain of North-East Caspian Sea shelf is characterized by several types of accumulative underwater plains according to genesis, morphological and hypsometric features:

- Alluvial-marine plain of the coastal seaside (avandelta)
- A flat transition zone with a continuation of water streams of the amphibious state with hydrophilic vegetation is subject to occasional flooding and reliction due to seasonal variations in the sea level and surges caused by wind. Further in the sea parallel to the previous one there is a strip where the underwater shoals give the plain a slightly wavy appearance.
- The outer, sloping strip of the alluvial-delta plain is characterized by an increased incline, crushed sediments, giving way to the strongest water streams. Its boundary is considered as the continental slope — a conventional line, after which the majority of river streams is not observed.
- The sea plain developed by downward currents occupies the shallowest coastal parts of the water basin. A flat, dry plain has migrating external and internal boundaries. The alternating flooding and reliction does not cause a significant transfer of sandy-muddy material, but only the leveling of the surface.
- The sea plain formed by currents and wave disturbances occupies a major part of the sea bed. Within its limits, large accumulative ridges with a length of several up to dozen kilometers are developed. In some places the ridges are separated by a network of transverse roughs. The inter-trough uplands serve as the origin for submerged bars and banks, which often come to the surface with peaks and form small sand-shell islands — "shalygas".
- The sea plain with islands and shoals of complex origin is located to the west of the Bozaschy Peninsula and corresponds

to the underwater continuation of the sub-latitudinal neotectonic anticlinal fold. The accumulative islands and shoals formed far from the main shore are confined to the top of this anticlinal fold. Currently, in the Seal Islands area, in addition to Kulaly island, the Morskoy and Rybachiy islands are seen on the surface in the day time [Bolgov et al, 2007, Sydykov et al, 1995].

— In different periods of the late Pleistocene and Holocene the shelf of the North-East Caspian Sea became land and some elements of its relief have subaerial features. These include valley-like depressions, as well as such stable forms of the shelf relief as the Ural and Mangyshlak Furrows (Figure 2.2).

NCOC N.V. fields reviewed in this Monograph have the following relief features.

Kashagan. The eastern part of Kashagan is located on a slope site of the sea plain complicated with large accumulative forms, which under the impact of the wave currents partially change shape and move. The fine-grained material from elevations is removed and a layer of shells 0.2–0.3 m thick is accumulated on the surface (the initial stage is the "shalyga" type island). The western part of Kashagan is located in the water area with large depths and is almost entirely located on the northeastern slope of the Ural Furrow. This area is characterized by a more dynamic relief.

Kalamkas-Sea is located in the deep part of the Ural Furrow with the sea bed as a flat underwater plain.

Kairan is located both within a flat plain with intensive surge activities (eastern part) and on a slope site of the sea plain, complicated by large accumulative forms (the western part).

Aktote is confined to a flat plain with intensive surges. The sands composing the area are relatively well washed due to mechanical drift of silt and clay particles. Cavity heads are observed at tens meter distance to the west from the area.

Shores

The shores of Kazakhstan part of the Caspian Sea are low-lying starting from the delta of the Volga River to the Tupkaragan Peninsula and elevated further to the south in the Mangystau Region, to the border with Turkmenistan. The low-lying coastline of the North-East Caspian Sea is exceptionally dynamic, its shape changes along with the fluctuations in the sea level.

Given the structure, genesis and the age of the relief, which determine the features of the landscapes and the dynamics of modern coastal processes, a number of regions are defined [Nurmambetov, Akiyanova 1998]:

— Low-lying shores: the eastern part of the Volga delta, the intercoastal part of the Volga-Ural interfluve, the delta shore of the Zhaiyk river, low-lying dry shore from the Zhaiyk river delta to the lower reaches of the Zhem river (Emba river), the sors of Dead Kultuk and Kaidak, mostly dried shores of the Bozashchy peninsula, etc.

— The raised shores: the Tupkaragan peninsula, abrasion shores with an active cliff to the south of the Kuryk village, to the north of the Kazakh Bay and along the Kendirli-Kayasan plateau.

Bathymetry

The North Caspian is the shallowest part of the Caspian Sea. It accounts for more than 24.3% of the sea area and 0.5% of the sea volume. The deepest part of the North Caspian Sea is on the border with the Middle Caspian and reaches depths of 15–20 m, averaging at 5–7 m. The major part of this area (68%) is less than 5 m deep.

The north-eastern part of the Caspian Sea is shallower than the north-west — averaging 3.3 m and 5.6 m depth respectively. Depths of 0–5 m occupy 88% of the area in the east (Figure 2.2). A large shallow water zone is located in the southeast close to Bozashchy Peninsula. It serves as the foundation to the archipelago of the Seal Islands including the largest Kulaly Island (73 km^2) and the Morskoy island (65 km^2). Small slopes of the sea bed relief extend to the nearby land parts, which leads to rapid flooding or drying of large areas and a significant change in the sea area with relatively small fluctuations in its level.

In the western part of the North Caspian Sea, water areas with depth range of 0–5 m occupy a smaller area than in the eastern part. The north-eastern part of the Caspian Sea is shallower, with the average depth of about 4.4 m [Kasymov, 1987].

Large depths are recorded in the western part of Kashagan field. During the period 2006–2016 the depths of 6.4–8.0 m were recorded at the long-term monitoring station EB-26. The minimum depth (6.4 m) was recorded in autumn of 2014. No trends of depth decrease were recorded in this area (Figure 3).

At long-term monitoring stations of Kashagan East, the range of depth (spring/autumn 2006–2016) was 3.1–4.8 meters with the minimum of 3.1 m recorded in autumn of 2009 at EO-EV-13 station.

The deepest water areas at the Company's facilities were recorded at Kalamkas-Sea field (up to 9.0–10.0 m). Depth distribution in Figure 2.3 indicates a certain trend in decrease of depths in spring at the Kashagan East and Kalamkas-Sea by 2014–2016.

Year-to-year changes of the sea depth from spring to autumn are characterized both as decrease and increase. The average depth change from spring to autumn was about 20 cm. The maximum depth decrease by autumn was 2.0 m (Kalamkas-Sea, 2013), the maximum increase in the sea depth from spring to autumn was 1.3 m (Kashagan East at EO- EB45 station in 2008).

Sea Level

The actual level of the Caspian Sea is a composition of long and short term changes (seasonal fluctuations, surges).

The seasonal course of sea level reflects fluctuations in the water content of rivers flowing into the Caspian Sea, the Volga River inflow from April to June, when its volume reaches peak levels, plays a decisive role in the spring-summer rise of the sea level. The major water accumulation in the sea occurs in June–July. The average monthly maximum of the sea level is also recorded mainly during this period. The lowest sea level is mostly recorded in December–February.

Long-term fluctuations of sea level. A unique peculiarity of the Caspian Sea is difficult-to-

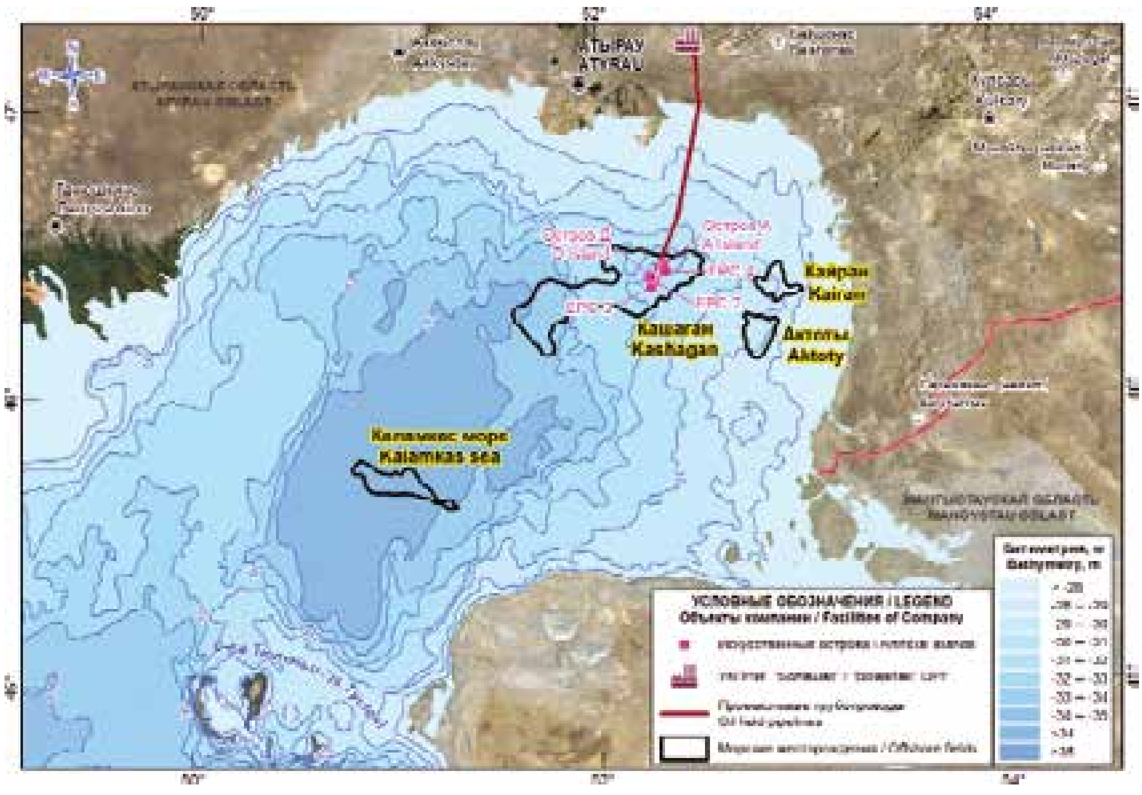


Figure 2.2 Depths of the North Caspian Sea

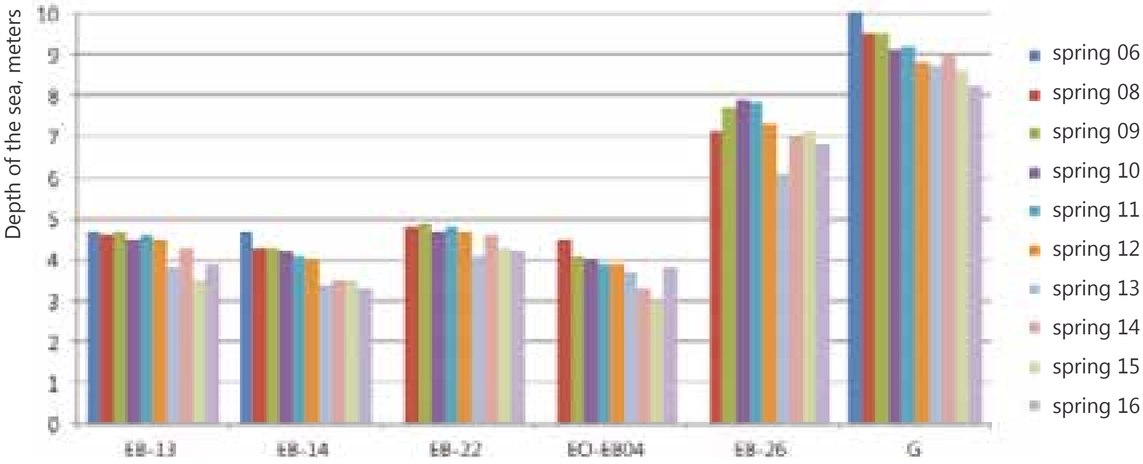


Figure 2.3 The depth change trend in Kashagan East (EB12, EB14, EB22, EO-EB04), Kashagan West (EB26) and Kalamkas-Sea (G). Spring 2006–2016

forecast long-term fluctuations of the level.

In the second half of XIX century the average Caspian Sea level was -26.0 m with deviations up to 0.8 m. In XX century, the amplitude of fluctuations reached 3.0 m. The rate of sea level drop in 1929 – 1940 was 16.5 cm/year, while the rate of sea level rise in 1978 – 1995 was 18.5 cm/year. At the same time, sea water levels varied between 8 and 40 cm. The current rise of the Caspian Sea levels has continued over 18 years (1978 – 1995). During this period the sea level increased by 2.5 m and by 1996 reached minus 26.6 m mark. Average rate of the sea level rise in that period was about 14 cm/year, and in some years – up to 36 cm. The average annual value of seasonal levels in the Caspian Sea is 40 cm. In 1995, the increase of sea level slowed down and since 1996 insignificant decrease of sea level has been observed; the level stability has been observed since 2006 (Figure 2.3–2.4). Maximum values of the average annual level decrease were recorded in 2011 and 2015 (25 and 19 cm accordingly). In 2016, the average annual sea level reached the level of minus 27.99 m.

It is interesting to note a steady trend of the average annual sea level drop since 2006, both according to official data (RSE Kazhydromet, CASPCOM), and to the results of level measurements conducted by NCOC N.V. directly at Kashagan field (Figure 2.4). Figure 6 shows that the course of the sea level at Kashagan is practically repeating the course of the average annual (baseline) level of the Caspian Sea.

Surges

Relief features and active winds are the factors contributing into formation of surges which lead to fluctuations of the sea level. At the northern and eastern coasts up-surges are caused by different direction winds from north-east to south. With depth decrease, the rise of the level per unit of distance increases. With the equal height of up-surge wave in the open sea, surge level in the bay is higher, while in open coastal areas it is lower.

Ice cover in winter reduces the range of surge fluctuations (by 3–5 times). A wide fast ice formed in severe winters at the eastern coast dampens the surges almost completely. During mild winters the fast ice is not formed or it is crushed by strong winds. Up-surges in such periods are followed by ice-drift to flooded coastal areas.

The coastal zone of the pre-caspian depression sees significant changes in hydro-morphological, hydro-chemical and environmental processes caused by surging fluctuations of the sea-level. During the year from 3–5 to 15–20 up-surges and down-surges are observed, thus the coastline near the northern part of the Caspian Sea is unstable and almost always migrates during 80–85% of time. Under average wind conditions, the extent of this migration is 3–5 km, in extreme conditions (during down-surge) – dried area may reach 8–12 km, and the flooding zone in some coastal areas is up to 25–50 km [Agip KCO, 2004] (Figure 2.5.)

Up-surges and down-surges in the NE Caspian Sea cause formation of a gradient on the sea surface, since the changes in altitude may not be even across the entire sea surface. The highest level changes occur on the windward coast (up-surge) or the leeward coast (down-surge) with the minimum sea level changes recorded in the central part of the sea, the most distant part from the coast ("node"). This is illustrated in Figure 2.6 [Hydrometeorological data, NCOC N.V., 2017].

The eastern wind causes a drop of the sea level in the NE Caspian Sea coast and an increase on the western coast of the North Caspian Sea.

Duration of surges widely varies from several hours to several days. Frequently, the surges last for 2–3 days, with maximum duration of 6–8 days.

The seasonal occurrence of maximum surges may be observed in the North Caspian Sea. The maximum frequency may be observed in autumn (October–November, 25%), in summer (June–July, 21%) and in spring (April–May 21%) during the long and strong winds directed toward the shore. In other months, the frequency of surges varies between 5 and 10%. The lowest frequency of surges (about 1%) is in February.

The highest and less frequent surges are typical for spring and autumn. A surge about 70 cm may be expected in any month of the year, and over 100 cm — with a greater probability in spring and autumn. Surges over 200 cm are most frequent in spring.

Table 2-1 presents the values of the sea level at particular wind directions.

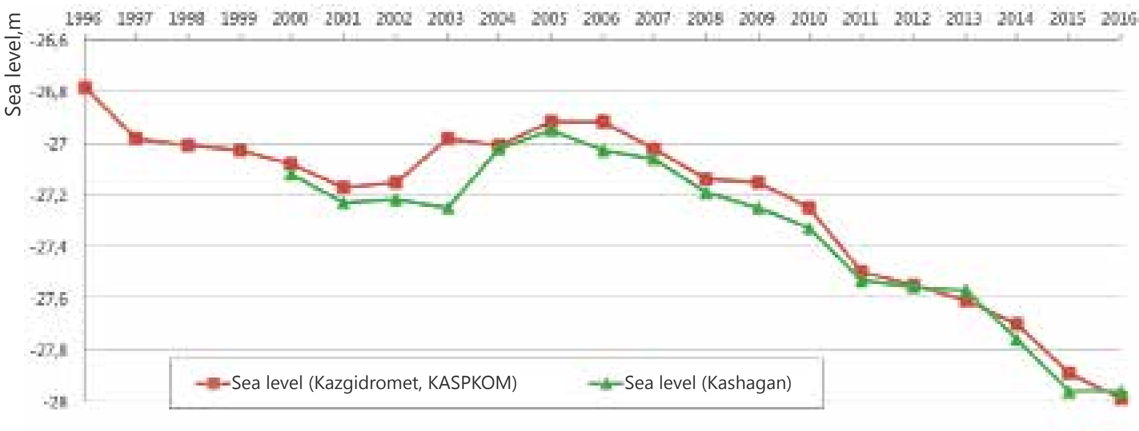
The information on actual values of up-surges and down-surges in the area of Company's facilities is of a great interest. The results of observations [Hydrometeorological data, NCOC N.V., 2017] conducted in the area of Kashagan East from 2005 to 2017 are given in Tables 2.2. and 2.3.

On October 23–24, 2004, strong and extensive (more than 2 days) winds of western direction resulted in a storm surge of sea water occurred on the eastern coast of the North Caspian from the Zhaiyk delta to Burinshik Cape. According to the data of automatic sea level recorders installed by NCOC N.V. in the area of artificial islands Kairan and Aktote, the sea level increased by 2.4 m and 2.2 m, respectively. The wind speed over the sea in this area reached 14 m/s (Kairan).

Wind-Induced Waves

The parameters of wind-induced waves in the eastern part of the North Caspian depend on the depths of the sea, wind speed and direction, and presence of aquatic vegetation. In shallow waters, the formation of waves coincides with the wind direction, and after a few hours of its impact, the waving becomes steady.

Because of the shallow depths and screening effect of the Seals Islands archipelago and the Kulalinsky ledge, the height of waves in the eastern part of the North Caspian Sea does not exceed three meters. The zone of maximum surge is the region of the Ural Ferrow, limited by a 5–meter isobath, especially its south-western and eastern parts



Data provided by RSE Kazgidromet, KASPCOM and dynamics of level at Kashagan (as per NCOC N.V. data)

Figure 2.4 Dynamics of the Average Annual Level of the Caspian Sea

IN THE NORTH CASPIAN SEA, THE HIGHEST WAVE HEIGHTS ARE RECORDED IN ABSENCE OF ICE. WAVES CAN HAVE THE FOLLOWING CHARACTERISTICS:
WAVE HEIGHT — 3 M,
PERIOD — 10 SECONDS,
LENGTH — 85 M.

The highest frequency in the north-eastern part of the North Caspian Sea is the surges of the western and eastern directions [Panin et al., 2005].

The lowest rise and fall of waves is observed in summer months (May–July) with frequent cases of flat calm sea throughout the whole water basin in the northern part of the Caspian Sea. The average annual frequency of waves with a height of less than 0.5 m is 58.6%; 0,5–1,0 m — 27,5%; 1,0–2,0 m — 13%; 2,0–3,0 m — 0,8% and more than 3,0 m — 0,1%.

The average annual values of wind waves comprise approximately 1.4 points (Atlas of Atyrau oblast, 2014).

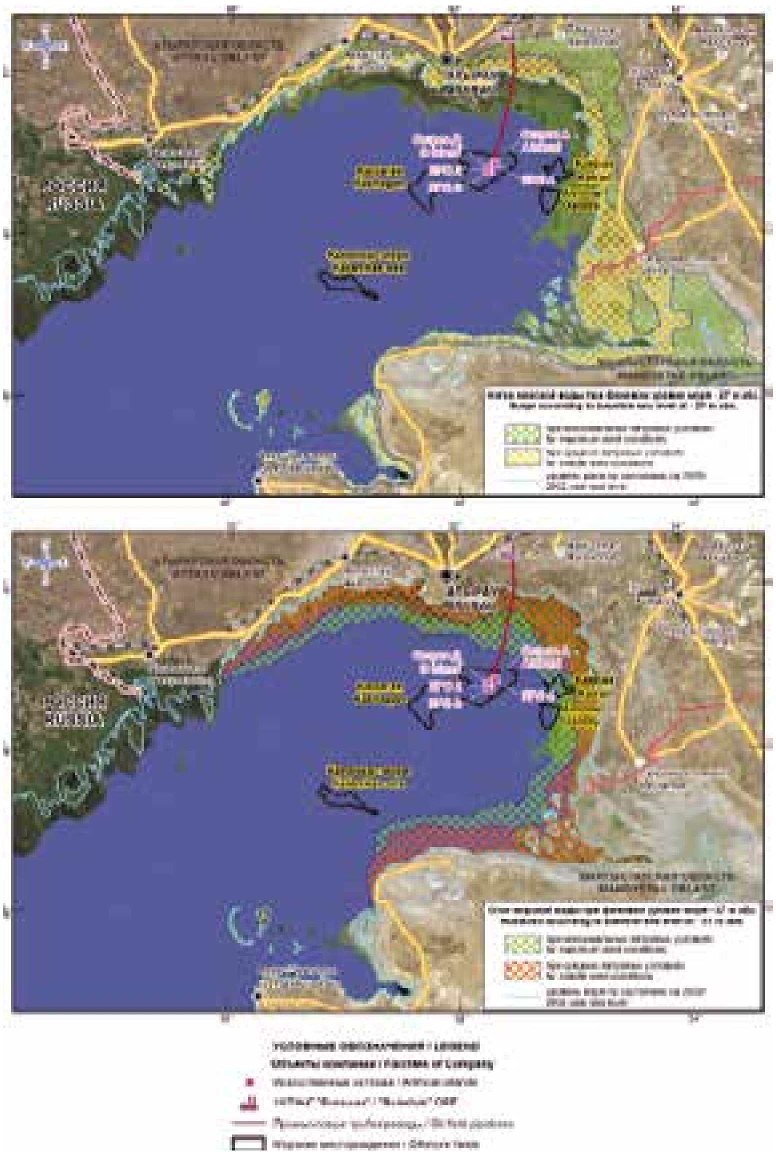


Figure 2.5

Zones of Surges Impact in the North Caspian Sea

The formation of ice in winter prevents the development of waves, isolating the water surface from winter winds. In warm winters during strong winds, ice storms may occur, when the fragments of crushed land ice, accelerated by wind and surge, may fall on the shore, causing a destructive effect on offshore facilities.

Water Temperature

The shallow water of the North Caspian Sea and continental climate of the region cause major seasonal changes in water temperature: from 0 °C in winter to 25 °C in summer months. The distribution of water temperature in the North Caspian Sea is very variable. The studies of long-term changes in water temperature in the North Caspian Sea show the relation of this parameter with the types of atmospheric circulation, air temperatures and ice cover. The average annual temperature of surface water layer in the Caspian Sea is 11–12 °C. In summer (July), average monthly surface temperatures of 24–25 °C prevail in the Caspian Sea [Atlas of Atyrau Oblast, 2014, Panin et al., 2005].

During the monitoring conducted by the Company in summer 2006 – 2016 at Kashagan, temperatures of the surface layer exceeded 27–28 °C (June, 2006, July 2014 and 2016). And in late June 2015, water temperatures exceeding 30 °C were recorded at Kashagan East.

The maximum daily range of water temperature fluctuations is observed during periods of

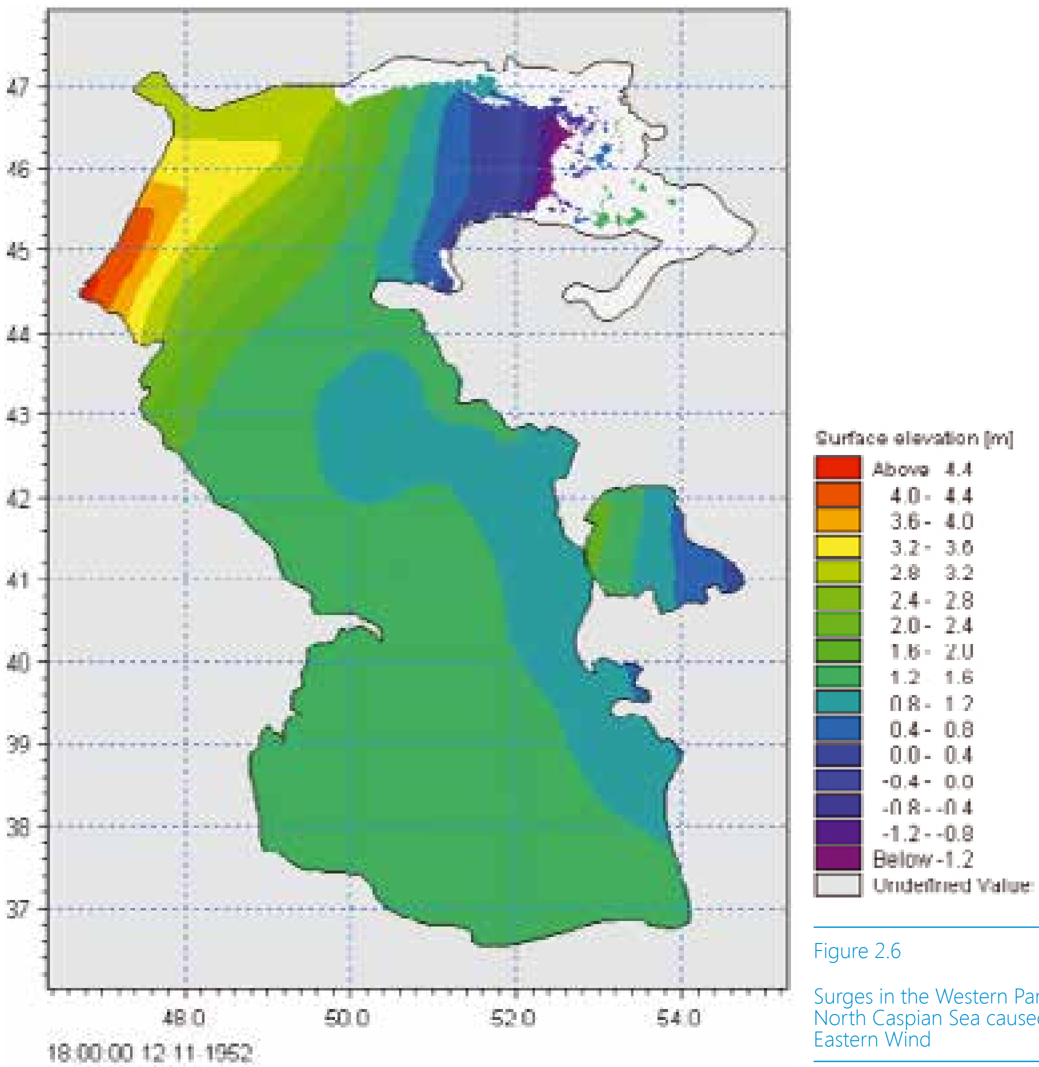


Figure 2.6

Surges in the Western Part of the North Caspian Sea caused by the Eastern Wind

Table 2-1 Maximum Possible Heights of Surges depending on Particular Wind Directions, Speed and Duration

Region	Wind direction	Height of surge against the baseline level, m: Wind speed, 10 m/s, duration 24 h	48 h	72 h	Wind speed, 20 m/s, duration 24 h	48 h	72 h
Zhaiyk River delta	SSW. S	0.40	0.60	0.78	1.27	1.66	2.00
Interstream area of Zhaiyk and Zhem rivers	SSW	0.55	0.78	0.95	1.63	2.20	2.53
From Zhem river to Prorva	SW	0.74	1.05	1.20	2.02	2.94	3.21
Komsomolets Bay	W. WSW	0.81	1.07	1.18	2.21	3.02	3.19
Bozashy Peninsula	WNW. NW	0.58	0.58	0.62	1.99	1.99	1.99

Table 2-2 Extreme monthly values of up-surges and down-surges based on the sea level measurements at Kashagan East, 2005-2017.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Max. Up-surge, m	0.38	0.91	1.17	0.82	0.99	0.87	0.46	0.58	0.54	0.62	0.75	0.95	1.17
Max. Down-surge, m	-0.88	-0.79	-2.08	-1.44	-0.88	-0.84	-0.71	-1.16	-1.15	-1.22	-1.09	-1.4	-2.08

Table 2-3 Monthly values of surges ange measured at Kashagan East in 2005-2017

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Maximum range, m	1.17	1.45	2.29	2.12	1.55	1.37	1.28	1.26	1.44	1.67	1.28	1.77	1.55
Average range, m	0.74	0.66	1.18	1.21	1.1	0.54	0.85	0.89	1.03	1.09	1.06	1.28	0.97

intensive warming and autumn cooling. The daily differences of water on clear sunny days also increase. At MS Peshnoy, the daily range of water temperature may comprise 2.2–2.3 °C. The annual range of water temperature at the Peshnoy MS is about 25 °C, the maximum water temperature at the Peshnoy MS exceeds 30 °C [The Caspian Sea.1992].

Salinity

The features of hydrological conditions of the North Caspian Sea are mainly determined by a great volume of rivers' inflow. The North Caspian Sea is the zone of river and sea water mixing and, therefore, it is characterized by quite uneven salinity distribution. The most significant changes in salinity are observed in the North Caspian Sea: from 0.1 ‰ in estuarial areas of the Volga and Zhaiyk Rivers to 11–12 ‰ at the boundary with the Middle Caspian Sea. Moreover, high water at the beginning of summer results in increase of salinity zones with up to 4 ‰.

The following factors have impact on salinity distribution in the North Caspian Sea:

- River inflow
- Wind-induced and gradient currents providing water exchange
- Evaporation
- Seabed relief determining the location of water with different salinity level along the isobaths lines.

The zones with the most desalinated water are located at the north-western coast of Kazakhstani sector of the Caspian Sea. This is caused by fresh water inflow of rivers (Figure 2.7 [Atlas of the Atyrau oblast, 2014]

Also, the distribution of salinity values depends on seasonal changes. In spring, under impact of flood water inflows, salinity in the NE Caspian is decreasing, reaching its minimum level usually in July. In high water periods salinity may remain at a low level until October. In summer-autumn period salinity gradually increases.

Analysis of salinity values measured during monitoring at Company's facilities is reviewed in this Monograph in Chapter 4 "Sea Water Quality".

Currents and Circulation of Water

Currents play an important role in the hydrological regime of the North Caspian Sea. They are determined by the wind, the Volga and Zhaiyk rivers inflow, and water density distribution. Wind currents play a dominant role in changes of the North Caspian hydrological conditions. Many studies have been devoted to modeling of wind currents. However, the study level of actual currents' speed in the North Caspian Sea is still insufficient due to the lack of long-term instrumental measurements [Akhverdiev, Demin, 1990; Panin et al., 2005].

IN THE SURFACE LAYER OF 3–4 M AND IN SHALLOW WATERS, THE CURRENT HAS A DIRECTION THAT COINCIDES WITH THE DIRECTION OF THE WIND.

Double-layered currents may occur in areas with depths of 5 meters and more. The wind currents develop and fade away rapidly (1–3 hours). Figure 2.8 shows a scheme of surface currents in the North Caspian Sea [Panin et al., 2005].

The seasonal variability of currents depends not only on the intra-annual wind variability, but also on the formation of stable ice cover in the North Caspian aquatic area in winter.

According to available data, average speed of current is 15 cm/s. The maximum speed of current can reach 70–90 cm/s. [Agip KCO, 2004].

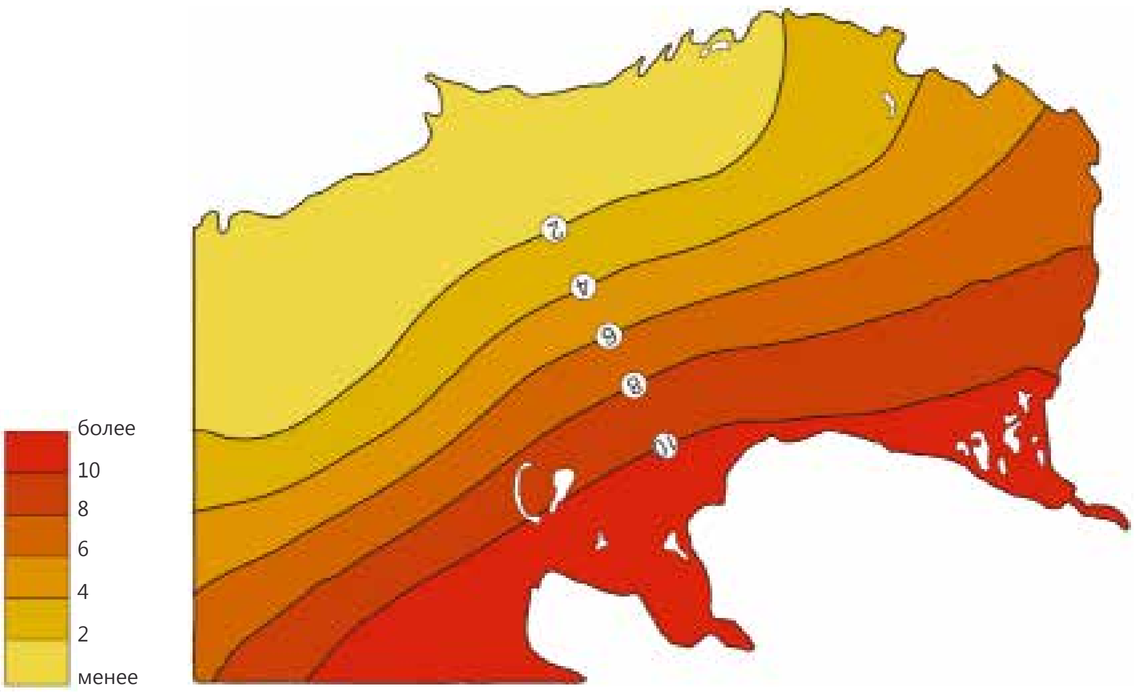


Figure 2.7 Average Long-term Salinity of the Water Surface Layer, Isohalines in ‰.

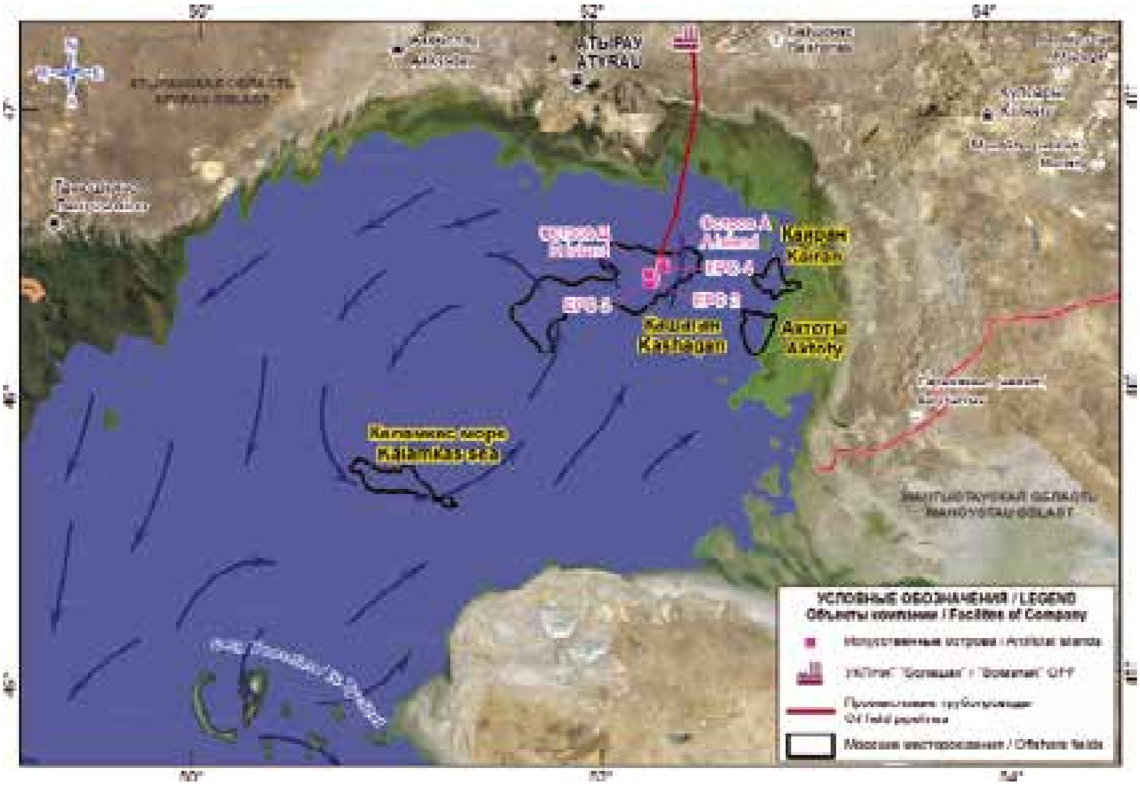


Figure 2.8 Surface Currents based on Instrumental Measurements Data

The annual rose of currents at Kashagan East is presented in Figure 2.9. The measurements were carried out in 2003–2009 by hydromet department of the Company [Hydrometeorological data, NCOC N.V., 2017] using an acoustic Doppler current profiler (ADCP).

The resulting frequency distribution in this diagram can be considered as the average conditions for the sea surface in an ice-free period.

Ice Conditions

The Caspian Sea freezes annually only in its shallow northern part. Deep-water areas of the Middle Caspian Sea are almost always free from ice. The eastern part of the North Caspian Sea is an area with a 100% probability of ice formation during the cold period. In cold winters, the first ice appears in the extreme NE part of the sea in early November. By the end of November, ice formation rapidly spreads across the water area, covering the northeastern coast, including the seashore of the Volga and Zhaiyk rivers. In warm winters the first ice can be formed on the

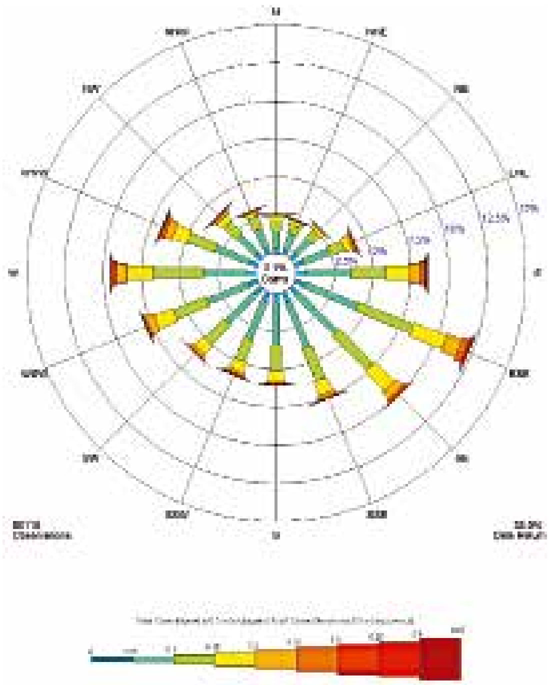


Figure 2.9 Annual Rose of Measured Currents at Kashagan East

seashore of the Zhayik River in early December, and in the second decade of December — in the deeper part of the North Caspian Sea.

In the average severe winter, the ice season in the North Caspian Sea may last for 3–4 months. In the abnormally cold winters, the ice season increases to 4–6 months.

IN KASHAGAN AREA, THE MAXIMUM DURATION OF THE ICE PERIOD IS 4–5 MONTHS.

The ice cover of the North Caspian Sea in different winters is determined not only by the area and volume of the ice formed, but also by the features of its development: the boundaries of the ice cover distribution, the predominance of certain forms and age types of ice, and its distribution over the water basin.

Long-term observations indicate that ice melting begins in the second half of February under average hydrometeorological conditions. First, the open areas of the North Caspian Sea become free of ice, and then its northeastern part. In late March — early April, the sea gets completely free of ice.

Available data acquired during observations of the ice cover directly at the Company's facilities [Hydrometeorological data, NCOC N.V., 2017] allows expanding the knowledge about the ice season far from the shoreline of the Caspian Sea northern part. The available data on the freeze-up dates shows that the beginning and the end of the ice season significantly vary from year to year (Figure 2.10 and Table 2-4.).

The ice cover of the Caspian Sea in various winters depending on thermal conditions is determined not only by the area and volume of the ice formed, but also by the features of its development.

A distinctive feature of the North Caspian ice cover is generation of fast ice. By the end of winter, it can extend for tens kilometers from the coast and even close with the fast ice of the western shore of the Caspian Sea. Even in very mild winters, the northern and north-eastern shores of the North Caspian Sea are blocked by fast ice and floating ice. The fast ice width, the ice thickness, and the size of the area covered by ice are determined by severity of winter in the North Caspian Sea. In moderate winters by the end of December, the total ice area is about 57.000 km^2 on the average; the area of fast ice comprises 80–90% [Caspian Sea, 1992].

According to data provided by satellite observations [HSVA Report, 1997], out of the areas under study (Kashagan, Aktote), fast ice can be formed in January–February only at Aktote field, which is explained by its nearness to the shore and shallow depths.

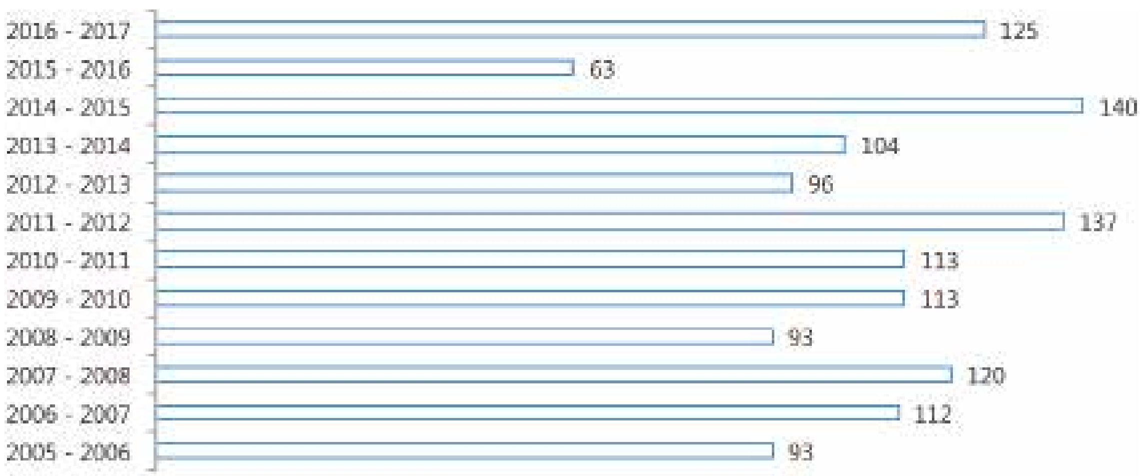


Figure 2.10 Duration (days) of Ice Seasons at Kashagan East

Table 2-4 Average Ice Periods

	Date of ice formation	Date of freezing	Date of ice melting	Date of last traces of ice	Duration of ice season
Kashagan East. Winter 1988–1989 — winter 2016–2017					
Average values	**05.12**	**12.12**	**04.03**	**23.03**	**109**
The earliest (longest)	12.12	20.09	08.02	13.04	140
The latest (the shortest)	30.12	04.01	01.04	02.03	63
Bautino Base. Winter 1988–1989 — winter 2016–2017					
Average values	**12.01**	**-**	**-**	**25.02**	**42**
The earliest (longest)	21.11	-	-	04.02	102
The latest (the shortest)	26.02	-	-	18.03	1

The ice thickness formation is uneven. The maximum thickness at the north-east by the end of February and beginning of March can reach 80–100 cm [Ivkina, Sultanov, 2012]. The average long-term thickness of ice in the North Caspian Sea ranges from 25–30 to 60 cm and can reach 130 cm in some areas with severe winters and thickness of rafted ice may reach 2–3 m [Kritskiy,1998]. The thickness of ice in shallow water areas increases until it reaches the sea bottom.

The age forms of drifting ice are different, from 5–10 cm ice crust, to 70 cm thick ice [The Caspian Sea, 1992, HSVA Report, 1997]. Ice thickness of more than 30 cm is most often formed as a result of fast ice breaking. High frequency of small- and coarse-grained ice (25–50%) indicates the continuous dynamic deformation (crushing) of drifting ice. The process of ice rafting is common for the North Caspian Sea. Subsequent adfreezing causes the formation of 1.5–2.0 m thick rafted ice.

Ice Dynamics

Small grounded ice ("stamukha") with 1–2 m in cross section and up to 3 m high is formed in autumn in the shallow coastal area. Stamukhas of winter origin are formed from 30–70 cm from winter or rafted ice. They can reach 500 m in cross section and up to 10–12 m in height. The locations of their potential occurrence are depths from 2 to 5 m.

In the second half of the ice season, the ice cover is impacted by dynamic factors, which are facilitating the fast ice breaking, ice compression and rarefaction, as well as ice rafting and formation of hummocks. Continuous ice hummocking occurs under impact of wind during winter seasons. In the eastern area of the North Caspian Sea, hummocking results in formation of ice ridges at the border of fast ice in parallel to its contour. A specific feature of the Caspian Sea is that the largest number of ice hummocks is formed in moderate, rather than in severe winters [The Caspian Sea, 1992]. The average height of ice hummocks according to the available references is 1.5–2.0 m, but can reach 5–6 m. The formation of ice hummocks can be observed far from the fast ice, near artificial facilities (Figure 2.11). Certain surveys have recorded the maximum height of the ice hummocks up to 12–14 m above the sea level [HSVA report, 1997].

Observations performed in 2002–2007 period from the vessels involved in NCOC N.V. projects allowed identifying a number of characteristics of ice hummocks along the route of vessels movement from the Bautino base to Kashagan. Observations from vessels have shown that the maximum height of ice hummocks can reach about 4 m, the average height of ice hummocks is 0.51 – 0.64 m (Table 2-5).

The general transfer of ice from the Ural Furrow and Mangyshlak Bay to the southwest to the Chechen Island is a general direction of ice drift. In the Ural Furrow, ice breaking and drifting can occur throughout the whole winter.

During surge winds, the ice drift is directed to the west and southwest. Usually, fast ice breaks caused by surges result in generation of cracks and dilutions along isobaths. Sometimes they are tens kilometers long. Interaction of drifting ice with the seabed causes erosion of the bottom (traces of scoring of the bottom or furrows).

Figure 2.11 Ice Cover in the North Caspian Sea and NCOC N.V. Operational Facilities

For the first time, they were described by B.I. Koshechkin back in 1958. They had the form of long, often rectilinear furrows extending from tens of meters to several kilometers. According to the published data, the depth of bottom scoring is usually limited to the upper 3 to 5 cm layer of bottom sediments, and according to some data the grounded ice ("stamukhas") penetrate into the seabed to 0.7–1.0 m depth on average [Blogov et al., 2007].

Company's surveys allowed observing some cases of bottom scoring up to 1.30 m, the orientation of furrows was most often from the SSW to the ENE. At the depth of the sea up to 1.5 – 5.0 m (Kashagan), approximate number of scoring cases is up to 20–50 per kilometer, maximum — over 100 furrows per kilometer.

The drift velocity, as a rule, represents a small percentage of the wind velocity, and is limited by the distribution of ice. The typical drift velocity is 0.3 m/s, but can reach 1 m/s and higher. Ice tends to drift in the same direction as the wind, but it also varies, especially when ice concentration is high.

Table 2-5 Statistical Characteristics of Ice Hummocks Heights, Meters

Parameters	Bautino-Kalamkas-Sea area	Kalamkas-Sea – Kashagan West	Kashagan West-Kashagan East
Average value	**0.63**	**0.64**	**0.51**
Lowest value	0.00	0.10	0.00
Highest value	4.00	4.00	4.00
Standard deviation	0.55	0.52	0.51
Number of observations	2330	2322	2478

One of the main sources of data to define the movement of ice is the analysis of satellite images [Hydrometeorological data, NCOC N.V., 2017]. The ice movement speed can be defined by comparing two subsequent satellite images (Figure 2.12). Thus, according to MODIS data, in April 2012, it was defined that the drift speed of ice fields in the North Caspian Sea varied from 1.5 to 7.7 knots (1 knot = 0.514 m/s).

Climate

The climate is defined by a geographical position of the sea, conditions of atmospheric circulation, nature of the underlying surface, and orography of the coasts. The continental features pertaining to the climate of the Caspian Sea are most evident in the North Caspian Sea. The climate of the North Caspian Sea is formed under the influence of Arctic, Iranian and Turanian air masses. During the cold season of the year, air masses coming from the western spur of the Siberian anticyclone dominate here: during the warm period they are replaced by overheated tropical masses from the deserts of Central Asia and Iran. Under the influence of such air masses circulation, a continental and extremely arid type of climate is formed.

The average dates of climatic seasons occurrence in the North Caspian Sea indicate that the longest season is summer [Caspian Sea, 1992]. It may last 4.0–4.5 months:

Spring	15-25 March
Summer	15–20 May
Autumn	20–30 September
Pre-winter season	25 October–5 November
Winter	30 October–10 November

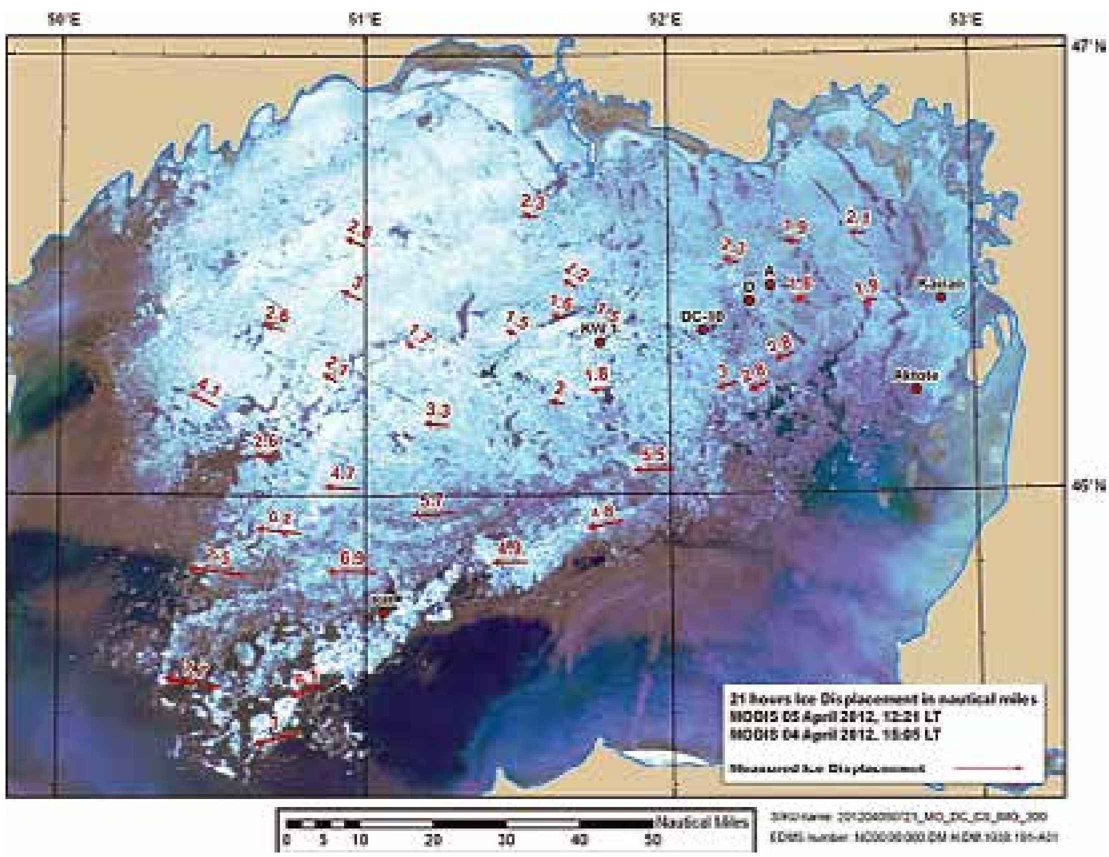


Figure 2.12 Movement of drifting ice generated on the basis of two MODIS images, which are separated by 21 hours. April 2012

The average temperature over the last decade (2007–2016) in Kazakhstan was +6.50 °C and exceeded a standard rate for 1961–1990 period by 1.01 °C; this is the second largest positive anomaly, after a record-warm decade in 1997–2006. On average, across the territory of Kazakhstan, and for 1976–2016 period, an increase in the average annual air temperature is 0.34 °C every 10 years, and in Atyrau region — 0.44 °C; in the Mangystau region — 0.48°C. The smoothed curve in Figure 2.13 is built on the basis of rolling smoothed data for 11 years; the anomalies are calculated with reference to the basic period of 1961 – 1990 [Annual Bulletin, 2017].

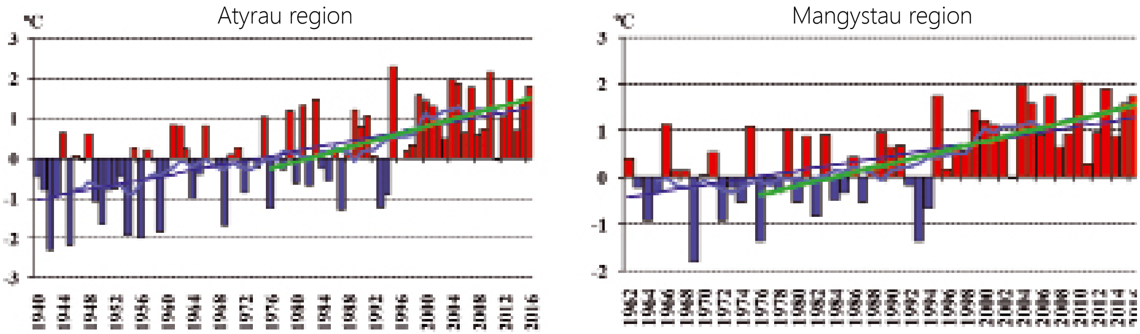
On average, across Kazakhstan, during the period of 1976–2016, there was a slight tendency in increase of annual amount of precipitation — by 7 mm every 10 years. Anomalies shown in Figure 2.14 are calculated with reference to the basic period of 1961–1990. The smoothed curve is built on the basis of rolling smoothed data for 11 years.

The year 2016 can be worth noting, because the average annual precipitation across the territory of Kazakhstan was 140% of the standard rate (in Atyrau region — 165%, in Mangystau — 174%). This is the maximum amount of precipitation observed during the period from 1941 to 2016.

Solar radiation

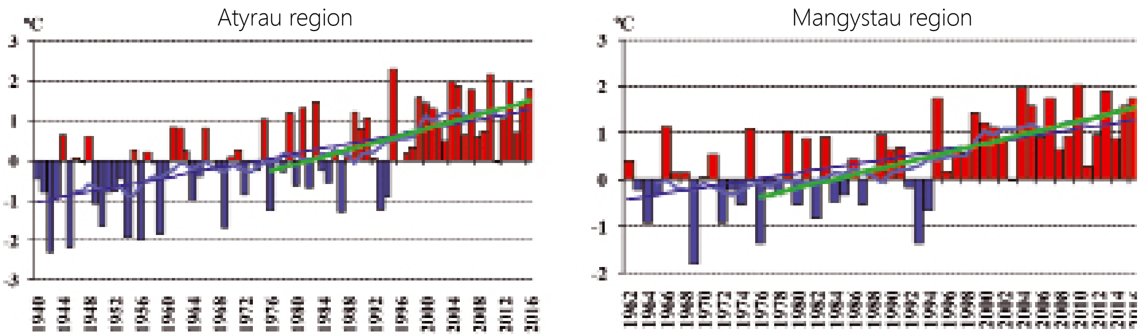
The average annual duration of sunshine in Atyrau is 2,635 hours [SP RK 2.04-01-2017]. The total solar radiation over the North Caspian Sea is 111–120 kcal/cm^2.

The data obtained at the metstation in Kashagan East (KE-1) allowed analyzing the solar radiation values (excluding night values). The results are given in Table 2-6 [Hydrometeorological data, NCOC N.V., 2017].



Note: *Linear trend for the period of 1976 – 2016. — green linez*

Figure 2.13 Time-Series and Linear Trends of Anomalies of Average Annual Air Temperatures (ºC).



Note: *Linear trend for the period of 1976–2016. — blue line*

Figure 2.14 Time-Series and Linear Trends of Anomalies of Annual Precipitation Amounts (in %).

Table 2-6 Solar Radiation Values by Months. Kashagan (W/m²)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Highest	562.2	734	851	957	1208	1085	1080	1076	881	822	663.1	506.6	1208
Average	103.54	175.19	245.67	339.57	351.71	398.17	369.84	333.33	316.61	222.66	121.10	71.66	267.17

Wind Direction and Speed

The prevailing wind directions in the North East Caspian Sea are closely related to seasonal barometric formations and the influence of the sea itself.

During the cold period of the year, the wind mode is determined mainly by the impact from spur of the Siberian anticyclone. Therefore, east and south-east winds prevail in winter. High repeatability of the eastern rumba remains in spring and autumn periods.

In the warm season (July), the winds of the south-western and western directions predominate over the water area.

The average annual wind roses according to observations at Kashagan and at the MS RSE Kazhydromet, are shown in Figure 2.15. The mid-annual rose winds along Kashagan, Peshny and Kulaly indicate that the winds of the eastern direction are the prevailing in the water area where the Company's oil fields are located.

The entire north-eastern part of the Caspian Sea refers to areas where the average annual wind speed is 5.0–5.6 m/s. The strongest winds are most likely in February–April, the weakest — in July–August. [Atlas of Atyrau region, 2014]. Also, according to the available data of RSE Kazhydromet, the climatic characteristics of the wind in the area under survey have the following features (Tables 2-7, Figure 2.16):

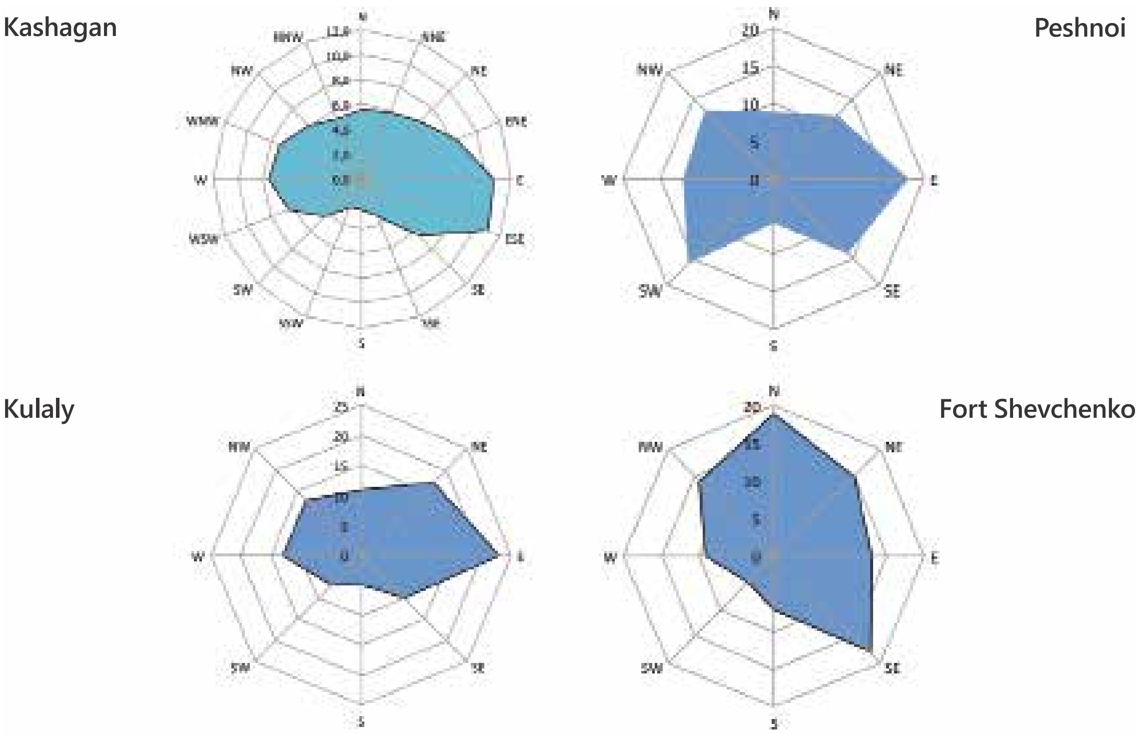


Figure 2.15 Wind Roses at the Kashagan Field and Kazhydromet Meteorological Stations

Table 2-7 Climatic Characteristics of the Wind

Wind Characteristics	Fort Shevchenko	Peshnoy	Kulaly
Average annual wind speed, m/s	5,2	3,3	4,9
Absolute maximum wind speed, m/s	40	28	45

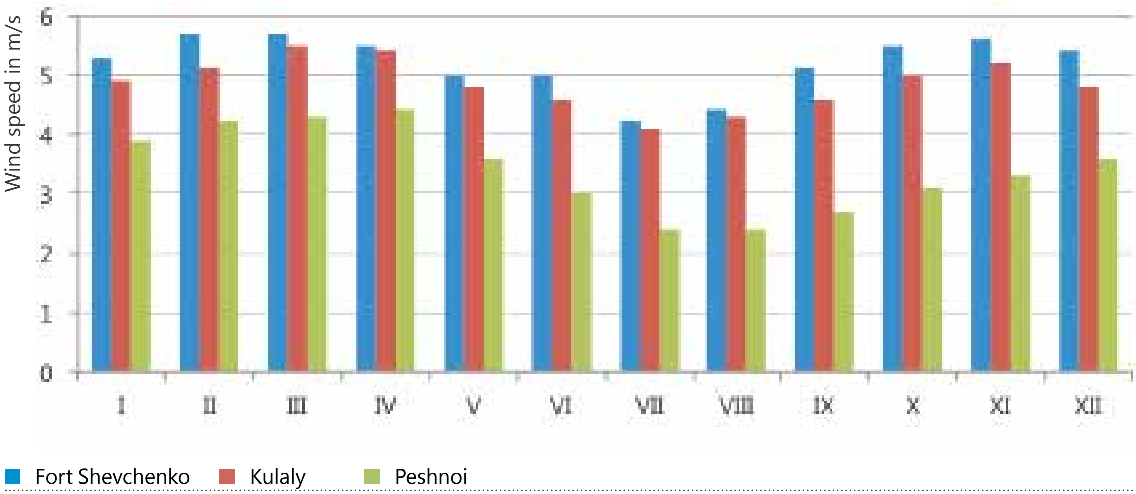


Figure 2.16 Average Monthly Wind Speed

Air temperature

Sharply continental climate of the region is characterized by major fluctuations of seasonal and daily temperatures. The absolute maximum temperature of the warmest month (July) for Atyrau is 44.6°C, and the absolute minimum temperature is -37.9 °C. In the area of the meteorological station (MS) Peshnoy, where the influence of the Caspian Sea is strong, the daily amplitude is about 8.5 °C.

Analysis of average monthly air temperatures at the north-eastern coast of the Caspian Sea indicates that January is the coldest month, and July is the hottest month [SP 2.04-01-2017].

The average annual air temperature in the north-eastern part of the Caspian Sea is 8.6–11 °C. The daily maximum air temperature falls on July, and it is 41 °C, the daily minimum air temperature is observed in January, and it is minus 37 °C (MS Peshnoy) [Atlas of Atyrau region, 2014].

The annual cycle of the air temperature shows that duration of the frost-free period averages 2/3 of the season. Temperatures above 30 °C can be observed from May to September.

The data on the air temperature at Kashagan field (A Island and KE-1 area) is given in Table 2-8 [Hydrometeorological data, NCOC N.V., 2017]. A comparative variation of air temperature by months is shown at Kashagan and other metstations in Figure 2.17. The average annual air temperature at Kashashan is 10.24 °C, which is slightly higher than the average annual temperature at the MS Peshnoy (9.20 °C).

Humidity and Atmospheric Precipitation

Air humidity is one of the most significant characteristics of weather and climate. The average annual relative humidity over the north-eastern part of the Caspian Sea is from 74 to 82%. The seasonal relative humidity has the following tendency: it is higher in winter and lower (up to 55–65%) in summer.

Relative humidity based on data obtained at Kashagan (KE-1) [Hydrometeorological data NCOC N.V., 2017] also shows that high humidity is observed in winter. These long-term observations at Kashagan have shown that highly saturated air (100% humidity) may occur at any time of the year, except for summer, when the maximum values may be only 90% (Table 2-9).

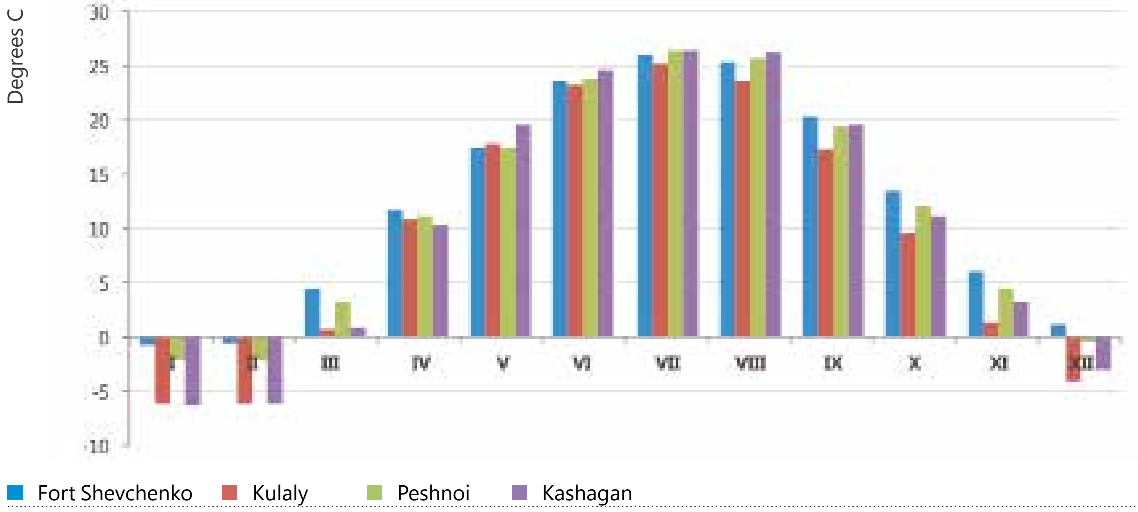


Figure 2.17 Average Monthly Air Temperature

Table 2-8 Monthly Statistics of Air Temperature. Kashagan (°C)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Per year
Average daily air temperature													
Lowest	-26,07	-22,56	-17,17	-0,74	9,08	15,78	19,38	17,98	9,66	-3,74	-16,08	-19,02	-26,07
Highest	2,79	4,41	12,98	20,21	27,82	32,05	33,36	32,46	31,65	23,6	13,4	7,3	33,36
Average	**-6,47**	**-6,08**	**0,90**	**10,25**	**19,47**	**24,57**	**26,49**	**26,43**	**19,65**	**11,16**	**3,30**	**-3,14**	**10,21**
Monthly air temperature values													
Lowest	-30,15	-26,02	-21,84	-3,70	7,70	13,60	15,87	14,60	7,10	-5,79	-17,90	-22,32	-30,15
Highest	5,50	7,90	17,20	25,43	34,17	36,51	38,47	37,60	36,70	26,70	14,20	10,00	38,47
Average	**-6,42**	**-6,13**	**0,90**	**10,28**	**19,47**	**24,55**	**26,45**	**26,24**	**19,58**	**11,17**	**3,27**	**-3,01**	**10,24**

The eastern coast of the North Caspian Sea, compared to other areas of the sea, is characterized by a higher aridity, which is due to a rare penetration of humid Atlantic air masses into this region. Pursuant to SNiP RK 2.04-01-2010 "Construction Climatology" and given humidification conditions, the area under consideration refers to the 3rd (dry) humidity zone.

Liquid form predominates in precipitation during the year. This is directly related to a longer period of positive air temperatures in this region. The highest average monthly amount of precipitation is in spring and autumn periods (Fig. 2.18).

The average annual amount of precipitation according to the meteorological stations of Fort Shevchenko-Kulaly-Peshnoy, is from 126 to 144 mm, respectively. Solid precipitation (snow, graupel) is observed from October-November to March– pril.

Table 2-9 Statistical Characteristics of Relative Humidity by Months, (%)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Lowest	42.6	44.7	16.3	18	13.1	11.3	11.2	10.8	19.4	27	39	40.2	10.8
Highest	100	100	100	99	97.3	93.8	91.7	92.2	97.4	98.2	100	100	100
Average	83.73	84.32	82.82	71.33	64.32	57.88	57.23	56.59	59.50	68.38	78.88	83.56	70.37

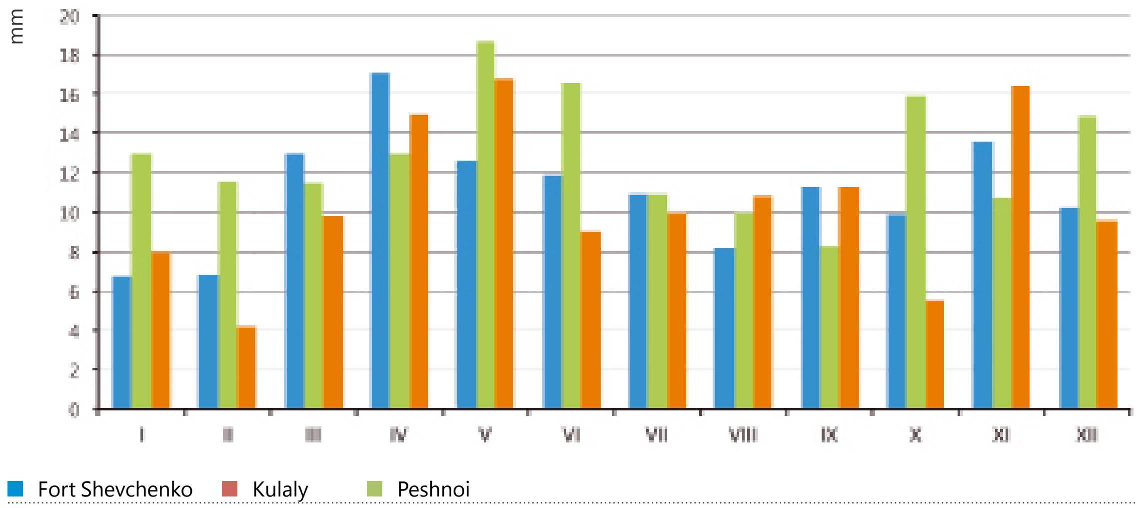


Figure 2.18 Average Monthly Rainfall

The average height of snow cover does not exceed 10–20 cm. The formation of a stable snow cover onshore and on the islands should be expected in the middle of December, snow melting — in the first ten days in March. The variability of these dates can be up to one month.

The duration of precipitation over the seasons is not similar. The longest duration of precipitation falls on winter. Summer rains are more intense, but not long.

Entry of Contaminants into the North Caspian Sea

The major sources of contaminants entry into the North Caspian Sea are the Volga and Zhayik Rivers. Virtually, 90% of the total amount of contaminants enters the Caspian Sea with river inflow. The Volga River inflow is about 80% of the total surface inflow into the sea. In certain, high-water years, the volume of river inflow can constitute 75% of the water volume of the North Caspian Sea [Quality of marine waters, 2015. Depending on the level of contamination of river waters, their contribution to the pollution of the northern part of the sea varies. For the beginning of the current century, concentration of petroleum products, surfactants and organochlorine pesticides in the water of the lower Volga is characterized by a decrease compared to the last decades of the last century. However, concentration of some heavy metals (iron, zinc, nickel and copper) remains high [Survey of the status and pollution, 2014].

The largest mass of contaminants entering from the Zhayik River is by 78% composed of the main ions, then come suspended substances (20%), followed by biogenes (1%), heavy metals (0.5%) and organic substances (0.5%). Table 2-10, indicates decrease of some contaminants entry in the period of 2006–2011. [Problems of Contamination, 2014].

In addition to river inflow, the entry of contaminants from the following sources is also critical: the Middle Caspian Sea, onshore and offshore oil production, eolian outflow, atmospheric precipitation, discharges from vessels, municipal sewage and sewage from industrial facilities, farmland, sources flooded during the sea level rise, as well as natural releases from the seabed.

A large number of different chemical compounds enter the marine environment, however, crude oil and petroleum products remain the main contaminants of the North Caspian Sea. At present, the major sources of hydrocarbons entry into the waters of the North Caspian Sea are oil transportation and water transport (fuel leakage or discharge of oily and ballast water), seepage of hydrocarbons from the seabed, industrial discharges, and offshore and onshore oil fields. The practice of oil and gas offshore fields development shows that even under routine operations oil fields remain a source of contamination. There is an opinion that offshore fields development can cause a release of 1– 30 tons of oil per year into the sea from one well [Tarassova et al., 2008].

The average annual volume of waste water discharges in Astrakhan region, from urban municipal units alone, was about 64 million

Table 2-10 Chemical Substances in the Water of the Zhaiyk River (downstream from the Atyrau city), tons/year

Periods	Main ions	Suspended substances	Biogenes	Organic substances	Heavy metals	Petroleum Products
2001-2005	2 154 227	1 381 093	4 493	420	5 822	420
2006-2011	1 054 043	408 144	7 660	116	1 039	116

cubic meters. The total volume of waste water discharged after treatment into the sea from the territory of Kazakhstan was about 820 thousand cubic meters. The main contaminants discharged into the Lower Volga are phenols, petroleum products, heavy metals (copper, zinc), surfactants and organic substances [Brekhovskikh et al., 2017].

Table 2-11 includes the information for comparing the volumes of contaminants entry from Russia and Kazakhstan [Caspian Sea, KAZKOM, 2011]

The Volga River makes the main contribution (up to 90% and more) to the chemical inflow from the territory of the Russian Federation, which is specified in Table. 2.11. Therefore, based on data provided in Table 2-11 and in Figure 2.19, it can be said that the main volume of contaminants in the sea, including petroleum products, comes with inflow from the Volga River.

Table 2-11 Estimated Volumes of Contaminants Input

Country	Sources	BOD, t/year	Nitrogen, t/year	Phosphorus, t/year	Oil, t/year
Russian Federation	Rivers	807 900	805 000	87 500	73 100
	Municipal units	16 000	5 000	1 400	3 800
	Industry	4 900	300	100	8 900
Republic of Kazakhstan	Rivers	13 200	6 000	600	400
	Municipal units	800	500	100	200
	Industry	2 900	7 100	100	1 800

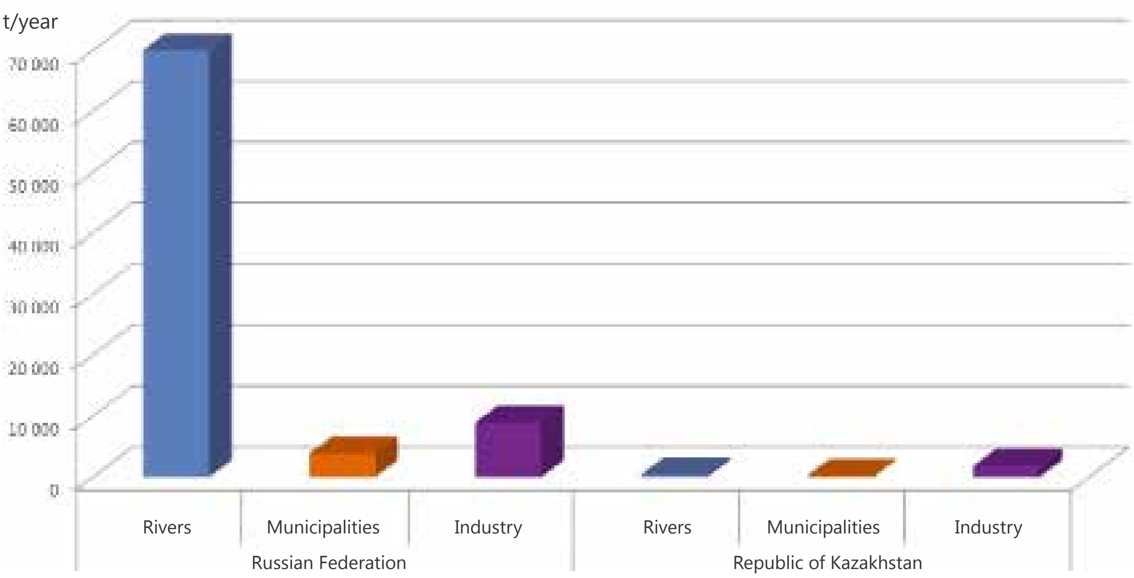


Figure 2.19 Estimated Values of Input of Petroleum Products into the Caspian Sea

Conclusions

The described physical and geographical conditions of the Caspian Sea (depth, climate, etc.) have a different impact on the status of the marine ecosystem. In addition to the described physical and geographical characteristics, the marine ecosystem is impacted by the uneven distribution of river inflow, the high ratio of the sea basin area to the area of its water surface. All these conditions/factors play an important role in functioning of the Caspian Sea ecosystems, both individually and in combination with each other.

It is possible to define some general features of the Caspian Sea that characterize its environmental conditions:

- Increase of the average annual air temperature over the last decade (2007–2016) in Atyrau region is 0.44 °C; in Mangystau — 0.48 °C.
- Shallow water in the North Caspian Sea and a continental climate in the region cause major seasonal changes in the water temperature. During summer period, the temperatures in the surface layer, exceeding 27–28 °C were observed in Kashagan area.
- In average severe winters, the ice season in the North Caspian Sea lasts 3–4 months. During abnormal cold winter periods, the ice season increases up to 4–6 months. In Kashagan area, the maximum duration of the ice period is 3 months.
- The north-eastern part of the Caspian Sea represents a wide shelf zone with depths of below 20 m.
- The tendency of a sea level drop is evident. The sea level drop in 2006–2016 period was about 1 m.

3. AIR QUALITY

Assessment of the state of air pollution was carried out within the framework of environmental monitoring in the Company's Contract Areas waters in accordance with the legislation of the Republic of Kazakhstan [Environmental Code of the Republic of Kazakhstan, p. 132, Rules for 2012 and 2014]. In 2006, air conditions were measured in spring and autumn periods and only in autumn in 2007. From 2008 to 2011, no surveys were carried out, they were only resumed in autumn 2012. In 2006–2007, measurements were taken in two fields — Kashagan and Kalamkas-Sea (Kalamkas) [Environmental Monitoring Reports, 2006–2007]. Starting from spring 2013, the number of stations has changed (see Chapter 1). Air monitoring was conducted in spring, summer and autumn periods [Environmental Monitoring Reports, 2012–2016].

The observed pollutants (P) for each field were determined by the Monitoring Program. Observable pollutants include:

- In 2006–2007: nitrogen dioxide (NO_2), carbon oxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), hydrocarbons C_1-C_5, suspended substances.
- In 2012: nitrogen oxides (NO and NO_2), carbon oxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S).
- Since 2013: nitrogen oxides (NO and NO_2), carbon oxide (CO), sulfur dioxide (SO_2), hydrogen sulfide (H_2S), hydrocarbons C_1-C_5, hydrocarbons C_{12}-C_{19}.

Determination methods:

- In 2006–2007, sampling of gaseous pollutants was carried out for a sorbent, suspended substances — on paper filters. The samples collected were analyzed by physico-chemical methods in the laboratory of the Scientific Analytical Center LLC (Almaty).
- In 2012–2015, the concentration was determined by the HANK-4AR type universal gas analyzer.
- Starting from autumn of 2015, samples for the determining of carbon oxide and hydrocarbons were again collected using the sorbent and were analyzed by physico-chemical methods in the laboratory of Kazekoanaliz LLC (Almaty). All other pollutant concentrations were determined by the HANK-4AR type universal gas analyzer.

The applied physico-chemical methods of sample analysis and the description of the HANK-4AR type universal gas analyzer are shown in Tables A2.1–A2.3 of Annex 2.

In addition, during the period 2006–2008, the drilled wells were tested. At Kairan, Kalamkas and Kashagan West fields, mainly exploration and appraisal wells were subject to tests. The purpose of the test was to determine the productivity of oil and gas bearing horizons. In Kashagan East, the test was carried out only on A Island. At the same time, the flow rate of wells was specified. During the wells testing, associated gas was flared. Therefore, flare plume monitoring was carried out to control the air pollution level [IEC Report, 2015].

In the flare plume monitoring period:

- The following pollutants were monitored: nitrogen oxides, carbon oxide, sulfur dioxide, hydrogen sulphide, hydrocarbons (gasoline), total hydrocarbons, soot.
- Determination methods: sampling of gaseous pollutants was carried out for a sorbent, soot — on paper filters, then the samples were analyzed using the physico-chemical methods in the Analytical laboratory for Environmental Protection LLC (Atyrau).

During all surveys, meteorological parameters were also measured: wind speed and direction, atmospheric pressure, humidity and air temperature.

Operations were mostly carried out on Kashagan East sites. The main sources of pollutants emission into the air in 2006–2013 were drilling (including well testing), construction and installation operations, in the subsequent 2014–2016 period — flaring units operated at A and D Islands.

IN 2006–2007 PERIOD, THE AMBIENT AIR MEASUREMENTS WERE TAKEN IN KASHAGAN EAST AT THE STATIONS LOCATED AT THE FOLLOWING OFFSHORE OPERATIONAL FACILITIES:

- A, D Islands, EPC2, EPC3
- Preparatory works sites and sites for construction of intra-field pipelines between A and D Islands, between EPC3 and D Island
- Preparatory works sites and sites for construction of Oil field pipeline
- Future DC Island sites (PLA5, PLA6, PLA10, PLAB).

The distance from the facilities was the following: 600–700 m from the islands border (sites), 200–400 m from the corridor border of the pipeline route. In total, there were 9 such stations in 2006 and 5 in 2007.

In addition, measurements were taken at long-term monitoring stations: EB-3, EB-13, EB-14, EB-22, EB-26, CEP-26 / 26B.

Almost in the same period (2006–2008) wells KEA-01, KEA-03, KEA-04; KEA-05; KEA-07; KE5-02 were tested on A Island. During the tests, flare plume air measurements were taken. For the purpose of monitoring, the most representative areas on the leeward side were selected at distances of 5 km, 10 km, 15 km from the island border and 5 km from the windward side, which was considered as baseline for these surveys.

In 2013–2014, air measurements were taken at 9 Level I stations (near the Islands); at 4 Level II stations and 6 Level III stations, all performing baseline functions (see Chapter 1, Figure 1.5).

In 2015, 2 stations were added to Level I stations on the Oil field pipeline route and 3 Level III stations.

In 2016, other 2 Level I stations were added along the intra-field pipeline route. In addition, the measurements were carried out at 10 Level III stations. At Level II stations no measurements were taken.

At Kashagan West sites, operations were carried out in 2006–2009. Air monitoring during this period was not performed, except for measurements in 2007 during the KW-2 well test. The measurements were carried out similarly to monitoring in Kashagan East: control points — 5 km, 10 km, 15 km from the drilling rig at the leeward and 5 km from the drilling rig at the windward side, which was taken as a baseline.

From 2011 to 2016, construction and drilling operations in these areas were not carried out. Wells were suspended. In order to monitor the state of the environment in these areas, two level I stations KW1-1000/245 and KW2-1000/245 were included in the observation. Measurements of the air state at these stations were taken in 2015 and 2016.

Aktote, Kairan and Kalamkas fields. In 2006–2007, no air measurements were performed at Kairan and Aktote, except for measurements during Kairan-2 well testing in 2007. The measurements were carried out similarly to East Kashagan.

At Kalamkas field, measurements were carried out in 2006 — at one long-term monitoring station (station G) and in 2007 — at two long-term monitoring stations — KALW-EB and KAL3-DC.

In 2011–2016 period, no operations were conducted in these fields; the wells were suspended. But in order to control environmental conditions, environmental monitoring was carried out at these fields. The air conditions were measured at:

- At Aktote and Kairan — at 1 Level I station — from 2013 to 2016, and 1 Level II station — from 2013 to 2015

— At Kalamkas — at 3 Level III stations — from 2013 to 2016.

3.1 Monitoring Results

Analysis of the air quality measurement results at fields was performed on the basis of the data acquired at monitoring stations of different levels (I, II and III) [Rules ..., 2012]. Pollutant concentrations are shown in mg/m^3. In order to explain how high or low these values are, the values in parentheses indicate a proportion of maximum one time of MPC (MPCm.o.t.), according to the Hygienic standards the "Sanitary-Epidemiological Requirements to Air in Urban and Rural Settlements". Peak values mean:

— In 2006–2007 — maximum pollutant concentrations

— In 2012–2016. — pollutant concentrations are above detection limits, but below the $MPC_{m.o.t.}$

Kashagan field

Kashagan East. Level I stations. In 2006–2007, peak concentrations for sulphuric pollutants -sulfur dioxide were recorded at up to 0.24 mg/m^3 (0.47 MPC) and hydrogen sulfide at up to 0.007 mg/m^3 (0.87 MPC). Small fluctuations in nitrogen dioxide concentrations with maximum of 0.086 mg/m^3 (0.43 MPC) were also recorded at the stations of the preparation and construction works of the Oil field pipeline between Islands A and D — IP-400/155 and in the area of the future island DC 05 — PLA 5-600/245 in autumn. All other concentrations at all stations were significantly lower than the $MPC_{m.o.t}$.

In 2012–2016, the concentration of most pollutants was below the detection limits, exceptions were the carbon oxide concentrations, which increased starting from 2.11 mg/m^3 (0.42 $MPC_{m.o.t.}$) to the maximum values in 2015 — 3.2 mg/m^3 (0.64 MPCm.r.) of 2013. The maximum value was recorded in spring at stations NP01-1000/W and NP01-1000/E (Oil field pipeline route). In 2013, peak concentrations were recorded for nitrogen dioxide up to 0.054 mg/m^3 (0.27 $MPC_{m.o.t.}$) and sulfur dioxide up to 0.049 mg / m^3 (0.1 $MPC_{m.o.t.}$). The maximum concentrations of these pollutants are recorded in summer at the EPC-2-1000/155 station. In 2015, peak concentrations were recorded for hydrocarbon groups C_1-C_5 of up to 27.5 mg/m^3 (0.54 $MPC_{m.o.t.}$); for hydrocarbon groups C_{12}-C_{19} of up to 0.544 mg/m^3 (0.54 $MPC_{m.o.t.}$) and sulfur dioxide of up to 0.042 mg/m^3 (0.1 $MPC_{m.o.t.}$). This data was recorded at the stations located in the area of construction works:

— NP01-1000/W and NP01-1000/E for hydrocarbon groups C_1-C_5 and hydrocarbon groups C_{12}-C_{19} in autumn

— DC01-1000/245 for sulfur dioxide in summer.

The range of main pollutant concentrations is shown in Figures 3.1 and 3.2.

Level II stations. The average pollutant concentrations during the monitoring period were below the detection limits. However, similar to Level I stations, a continued content increase of carbon oxide was observed with 1.7 mg/m^3 (0.34 $MPC_{m.o.t.}$) in 2012 and up to 3.74 mg/m^3 (0.75 $MPC_{m.o.t.}$) in 2015. Maximum concentrations were recorded in autumn and spring at stations 2L/KSH-08 and 2L/KSH-21.

In 2013, peak concentrations were recorded for nitrogen oxide — up to 0.12 mg/m^3 (0.3 $MPC_{m.o.t.}$) and hydrocarbon groups C_{12}-C_{19} of up to 0.544 mg/m^3 (0.54 $MPC_{m.o.t.}$) — station 2L/KSH-10 in spring.

In 2015, peak values were recorded for nitrogen dioxide of up to 0.026 mg/m^3 (0.23 MPC) in autumn at 2L/KSH-21 station.

In general, at Level II stations, the pollutant content in the air did not exceed the $MPC_{m.o.t.}$ and was below the detection limits. Peak concentrations of nitrogen oxides and hydrocarbons are most likely connected to the active navigation in the area, including the Company's support vessels movement. The increase in carbon oxide concentrations was assumed to depend on seasonal changes in the atmosphere.

Level III stations. In 2006–2007, peak concentrations for sulphuric pollutants — sulfur dioxide of up to 0.39 mg/m^3 (0.78 $MPC_{m.o.t.}$) and hydrogen sulfide of up to 0.0061 mg/m^3 (0.76 $MPC_{m.o.t.}$) values were recorded similar to values recorded at Level I stations. Small fluctuations in nitrogen dioxide concentrations with maximum of up to 0.066 mg/m^3 (0.33 $MPC_{m.o.t.}$) were recorded at long-term monitoring stations EB-3

Kashagan East

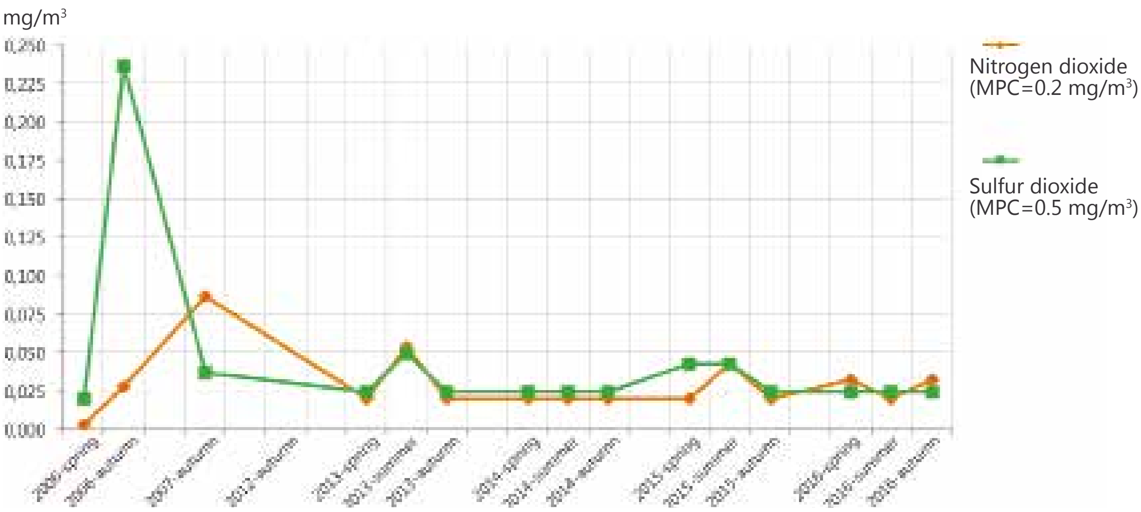


Figure 3.1 Range of the main pollutant concentrations at Level I stations during the monitoring period from 2006 to 2016 (nitrogen dioxide, sulfur dioxide)

Kashagan East

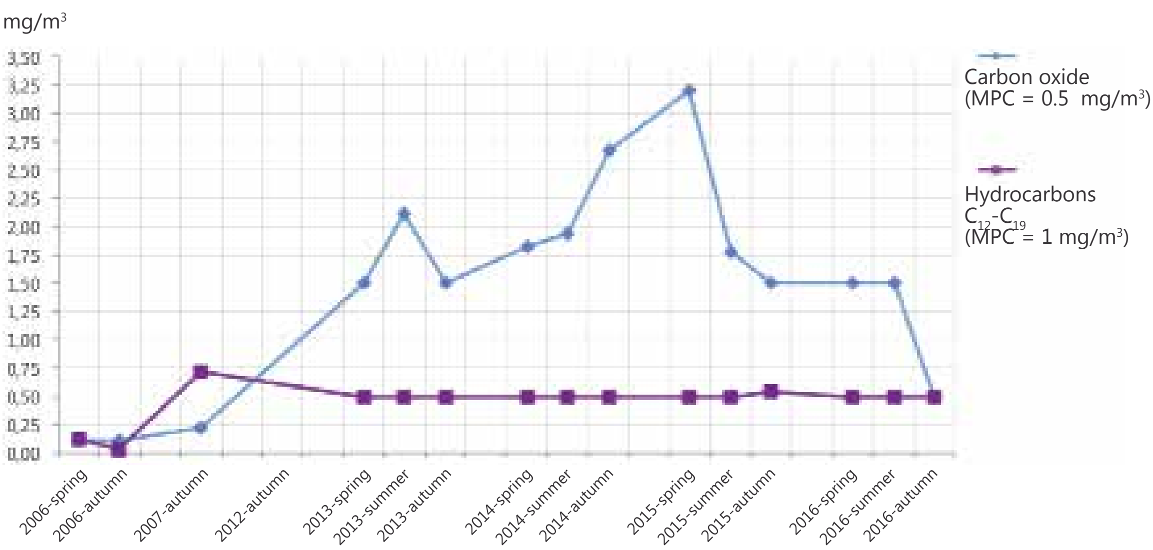


Figure 3.2 Range of the main pollutant concentrations at Level I stations during the monitoring period from 2006 to 2016 (carbon oxide, hydrocarbons C_{12}-C-$_{19}$)

and EB-13 in summer period. All other pollutant concentrations were significantly lower $MPC_{m.o.t.}$.

In 2012–2016, the pollutant concentrations were almost similar to Level I and Level II stations:

- They were in general below the detection limits, only carbon monoxide concentrations differed
- Which increased from 1.77 mg/m^3 (0.34 MPCm.o.t.) in 2013 up to 4.5 mg/m^3 (0.90 MPC) in 2015 at stations EB-26 in summer and EB-14 in spring.

In 2013 there were minor peak sulfur dioxide concentrations of up to 0.029 mg/m^3 (0.06 $MPC_{m.o.t.}$) and nitrogen dioxide of up to 0.035 mg/m^3 (0.18 $MPC_{m.o.t.}$), as well as an increase in nitrogen oxide concentrations to almost the value of Maximum Permissible Concentrations — 0,367 mg/m³ (0,92 $MPC_{m.o.t.}$). These concentrations were observed in the spring-summer period at EB-26 and EO-EB02 stations.

The range of the main pollutant concentrations at long-term monitoring stations (taken as baseline stations) is shown in Figures 3.3 and 3.4.

During well testing on A Island, maximum concentration of pollutants was observed at the distance of 10 km on the leeward of the island. Concentrations on the leeward were higher than the baseline values:

— In 2006, the following pollutants had the maximum values:

  - Sulphur dioxide — up to 0,055 mg/m³ (baseline — 0,0046 mg/m³)

Kashagan East

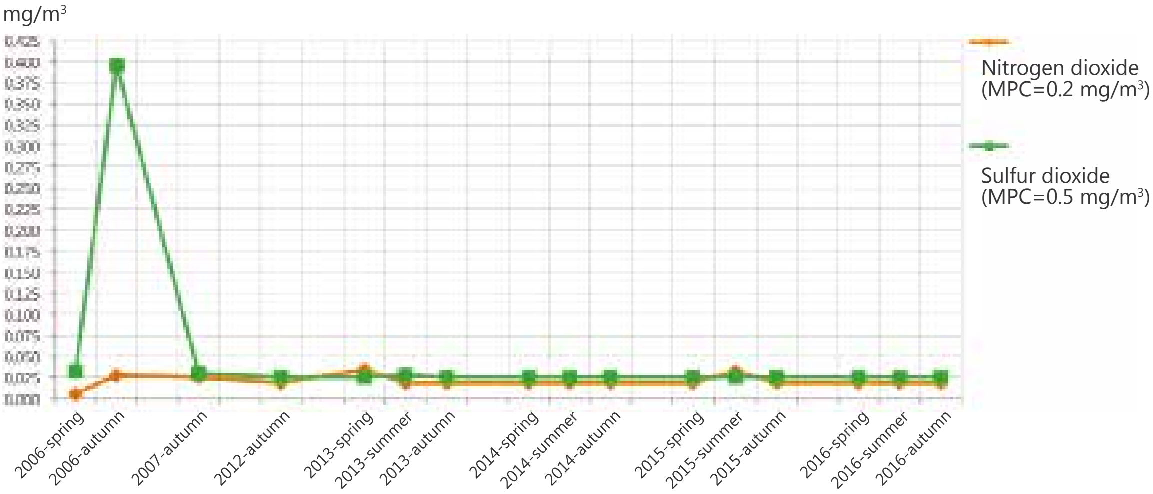


Figure 3.3 Main Pollutants Observed at Long-Term Observation Stations in 2006–2016 (nitrogen dioxide, sulphur dioxide)

Kashagan East

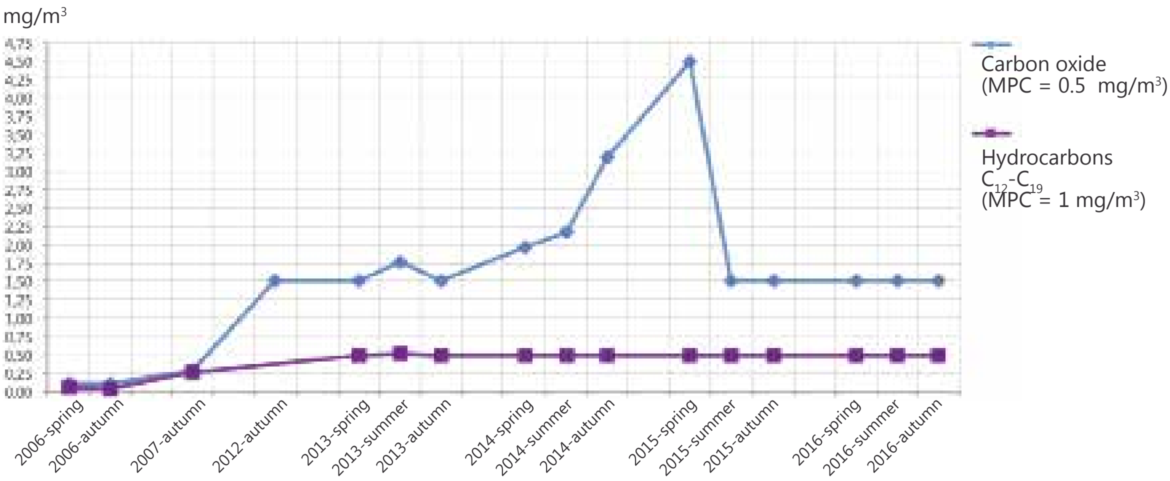


Figure 3.4 Main Pollutants Observed at Long-Term Observation Stations in 2006–2016 (carbon monoxide, hydrocarbons C_{12}-C_{19})

- Nitrogen dioxide — up to 0,043 mg/m³ (baseline — 0,002 mg/m³)
- Hydrogen sulphide — up to 0,0055 mg/m³ (baseline — 0,0013 mg/m³)
- Carbon monoxide — up to 0,38 mg/m³ (baseline — 0,26 mg/m³). Maximum concentrations were observed during KE A-03 and KE A-04 wells testing.

— In 2007, only one well KEA-07 was tested. Concentrations of hydrogen sulphide up to 0,0006 mg/m³ (baseline — 0,0001 mg/m³) and carbon monoxide up to 0.23 mg/m³ (baseline — 0.21 mg/m³) were exceeding the baseline concentrations. Concentration of other pollutants was at the level or below the baseline values.

— In 2008, during KE A-05 well testing, concentration of all pollutants (except for ash) was slightly higher than the baseline values, including:

- Sulphur dioxide up to 0,003 mg/m³ (baseline — 0,002 mg/m³)
- Nitrogen dioxide up to 0,022 mg/m³ (baseline — 0,015 mg/m³)
- Nitrogen oxide up to 0,003 (baseline — not found)
- Hydrogen sulphide up to 0,001 mg/m³ (baseline- 0,0006 mg/m³)
- Carbon monoxide up to 0,29 mg/m³ (baseline — 0,18 mg/m³)
- Hydrocarbons (gasoline) up to 1,8 mg/m³ (baseline — 0,6 mg/m³), three times higher than the baseline values.

Concentrations of ash were not found. Variation of pollutant concentrations during wells testing is presented in Figure 3.5.

Kashagan West. The results of the measurements showed that in 2007, during the well testing, pollutant concentrations from the windward and leeward sides were almost similar. Concentrations of hydrogen sulphide and hydrocarbons were above the baseline values. по Hydrogen sulphidey – 0,002 mg/m³ (baseline - 0,0007 mg/m³);

Underflare observations at Kashagan East

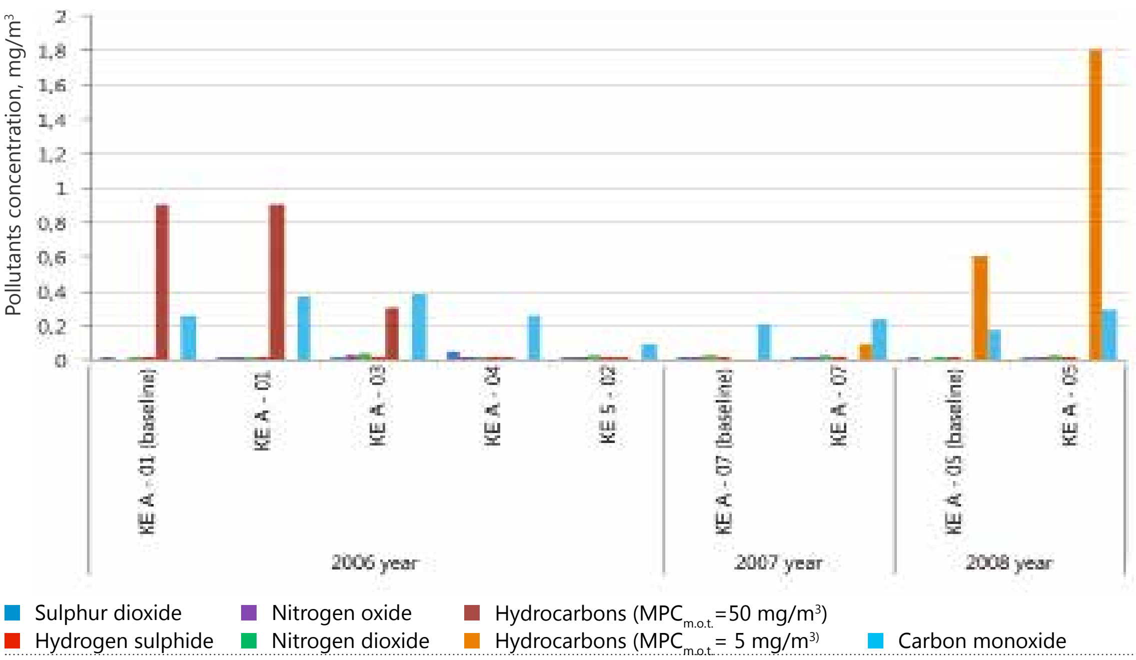


Figure 3.5 Pollutant Concentrations Observed during Wells Testing at Kashagan East in 2006–2008.

— Hydrogen sulphide — 0,002 mg/m^3 (baseline — 0,0007 mg/m^3)

— Hydrocarbons — 2,5 mg/m^3 (baseline — 0,02 mg/m^3).

Maximum concentrations were observed at the distance of 10 km from the drilling rig. It shall be noted that there was a certain impact from wells testing on air quality, which was limited to 10 km from the operation area.

IN 2015–2016 POLLUTANT CONCENTRATIONS WERE BELOW THE DETECTION LIMIT SHOWING THAT THERE WAS NO SIGNIFICANT IMPACT FROM THE COMPANY'S OFFSHORE FACILITIES ON AMBIENT AIR IN THIS AREA.

Aktote, Kairan, and Kalamkas Fields

The analysis of available data indicated the following:

Aktote. Generally, pollutant concentrations were below the detection limit at the Level I stations. In spring 2013, the highest concentration of nitrogen dioxide up to 0,115 mg/m^3 (0,57 MPC$_{m.o.t.}$) was recorded at AKT-1000/245 station. The highest concentration of nitrogen oxide up to 0.066 mg/m^3 (0,4 MPC$_{m.o.t.}$) was registered at the second level station (2L/AKT-05) during the spring-summer period.

In 2013–2015 (summer and autumn periods) concentration of carbon monoxide increased from 2,94 mg/m^3 (0,59 MPC$_{m.o.t.}$) to 3,53 mg/m^3 (0,71 MPC$_{m.o.t.}$) at AKT-1000/245 station. Variation of main pollutants concentration at I and Level II stations is presented in Figures 3.6 and 3.7.

Kairan. Generally, in 2007, during Kairan-2 well testing, pollutant concentrations were below the baseline values. The increase was observed only in sulfur dioxide values — 0.011 mg /m^3 against the baseline value of 0.0003 mg/m^3 (Figure 3.8). The maximum values were recorded at 10 km distance from the island.

In 2013–2016, the maximum concentrations were observed at both the Level I Stations (KRN-1000/245) and the Level II baseline stations (2L/KRN-01):

— In 2013 concentration of nitrogen dioxide was up to 0,022 mg/m^3 (0,11 MPCm.o.t.);

— In 2014 concentration of carbon oxide was up to 2,1 mg/m^3 (0,42 MPCm.o.t.);

— In 2015 concentration of nitrogen dioxide was up to 0,021 mg/m^3 (0,10 MPCm.o.t.),

Aktote

Figure 3.6 Main Pollutant Concentrations Recorded at Level I Stations during 2013–2016 Observation Period.

Aktote

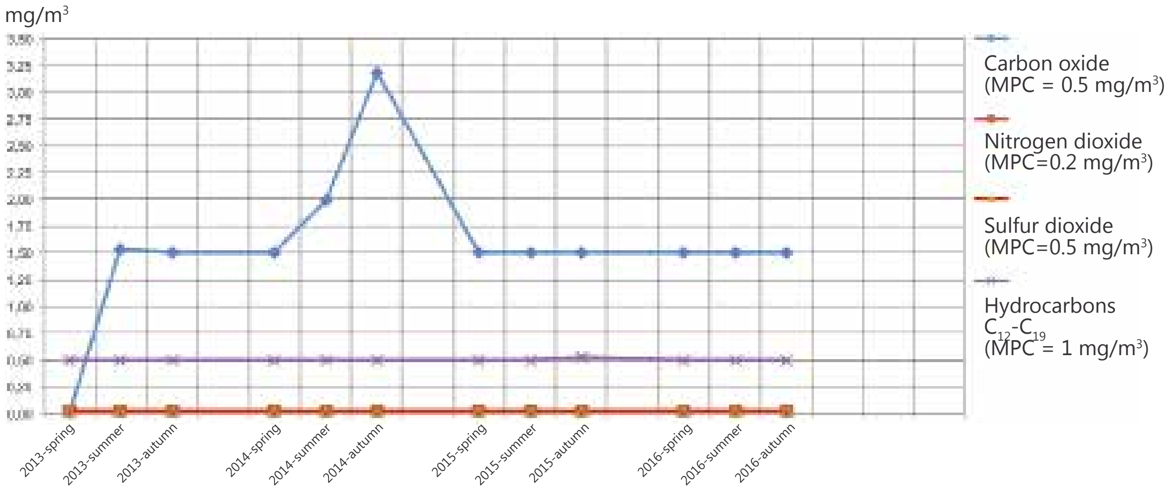


Figure 3.7 Variation of Main Pollutants Concentration at the Level II stations during 2013–2016 Observation Period.

concentration of hydrocarbons of group C_1-C_5 was up to 26 mg/m^3 (0,52MPC$_{m.o.t.}$) and concentration of hydrocarbons of group C_{12}-C_{19} was 0,554, mg/m^3 (0,55MPC$_{m.o.t.}$).

The maximum concentrations were observed in autumn 2013 and 2015. Variation of the main pollutants concentration at Level I and Level II stations is presented in Figures 3.9 and 3.10.

Kalamkas. Generally, in 2006 -2016 observation period, pollutant concentrations were below the detection limit. In autumn 2006–2007, except for high concentrations of sulphur compounds — sulphur dioxide — up to 1.19 mg/m^3 (0.4 MPC$_{m.o.t.}$) and hydrogen sulphide — up to 0,0128 mg/m^3 (1,6 MPC$_{m.o.t.}$). Concentrations of other pollutants recorded during this period had minimum values.

In 2013–2015, carbon monoxide concentrations had increased from 1,97 mg/m^3 (0,4 MPC $_{m.o.t.}$) to 2,9 mg/m^3 (0,6 MPC $_{m.o.t.}$). The maximum value was recorded at station G.

In 2013, maximum concentrations were recorded during the summer period for nitrogen oxide up to 0,194 mg/m^3 (0,5 MPC$_{m.o.t.}$) and nitrogen dioxide up to 0,043 mg/m^3 (0,2 MPC$_{m.o.t.}$) at KALW-EB13 station.

In 2015, the highest values refer to sulphur dioxide up to 0,026 mg/m^3(0,05 MPC$_{m.o.t.}$), nitrogen dioxide up to 0,038 (0,19 MPC$_{m.o.t.}$), and hydrocarbons C_1-C_5 up to 27.5 mg/m^3 (0,55 MPCm.o.t.). Maximum values were recorded during summer and autumn periods at KALW-EB13 and KALW/EC/5/124 stations. Variation of main pollutants concentration at Level III stations is presented in Figure 3.11.

Identification of Anthropogenic Factor Impact 3.2

During the period under consideration (2006–2016) the main operations were conducted at Kashagan field; therefore, the main volume of emissions had been released there.

In 2006–2007, the main emission sources included drilling rigs and construction–installation operations at the offshore facilities in Kashagan field, i.e. A and D Islands. Emission sources were mainly presented by power units of drilling rigs and lifting equipment — generators of 2,000 kW capacity. Besides, living quarter barges — LQBs had been used as well. Their number in certain periods was over 20 units. Operation of LQBs was provided by power generators. In general, their capacity was 300–600 kW, but some LQBs had more powerful generators — 1,000 –1,600 kW. Therefore, power units of drilling rigs, construction-installation equipment and LQBs with fuel combustion process were

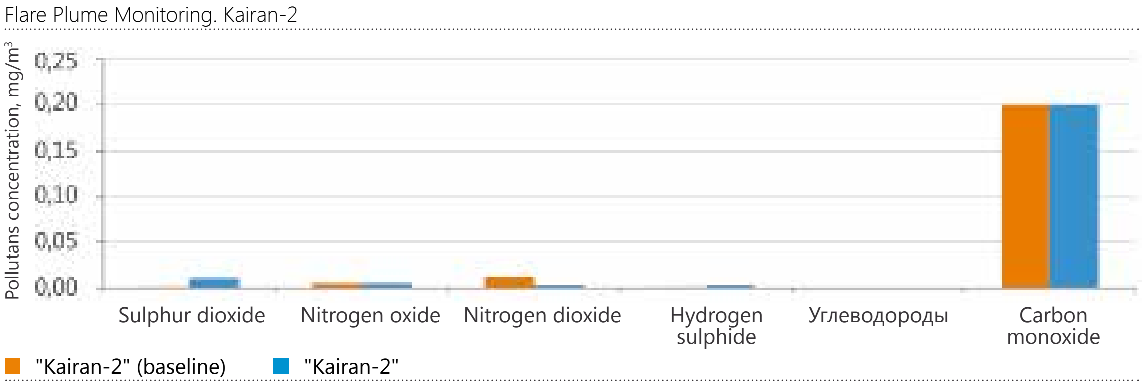


Figure 3.8 Pollutant Concentrations variability Recorded during Well Testing at Kairan Field in 2007.

Figure 3.9 Variation of Main Pollutants at Level I Stations in 2013–2016.

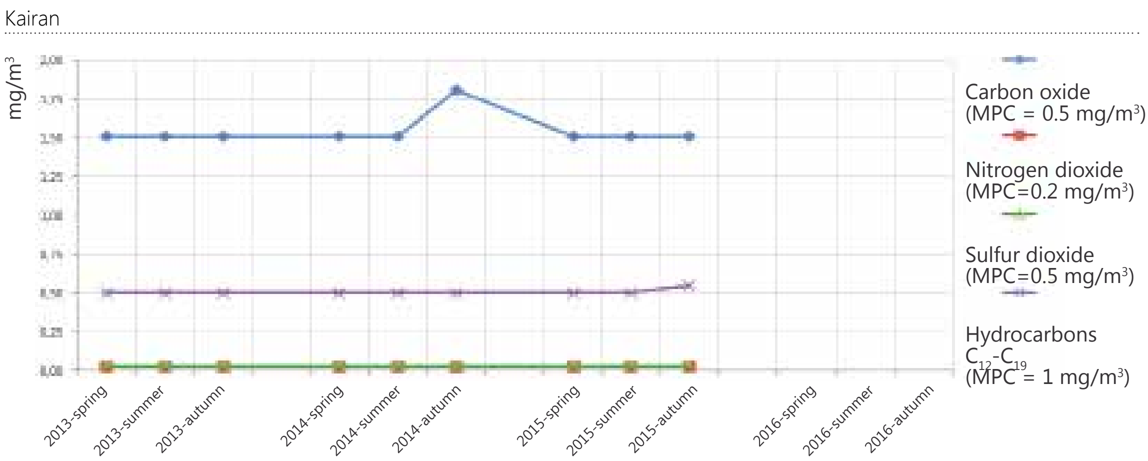


Figure 3.10 Variation of Main Pollutants at Level II stations in 2013–2016.

Kalamkas

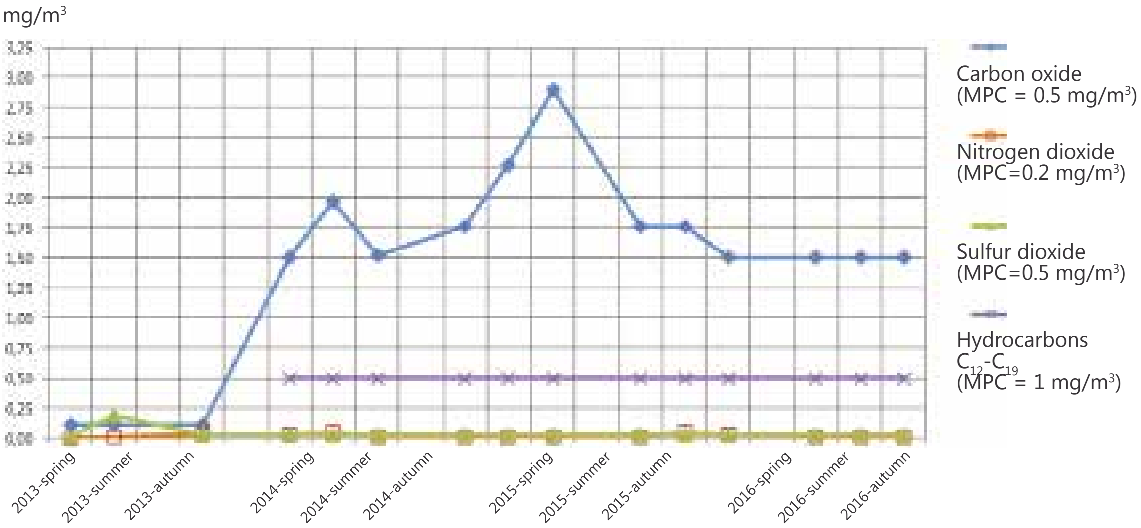


Figure 3.11 Main Pollutants Observed at the Level III Observation Stations in 2006–2016.

the main sources of nitrogen oxides, sulphur dioxide, carbon monoxide, and hydrocarbons emission. Thus, these pollutants were chosen for atmospheric air measurements.

According to the data provided by the Company [IEM Reports, 2007–2010], the volume of gross emissions from various sources for this period comprised (Table 2.17, Annex 2):

- 2006 — 1081 t. The main contribution was made by construction operations and well testing on A Island.
- 2007 — 1220 t. The main contribution was made by drilling, construction operations, LQBs on D Island.

According to MPE projects developed for Agip KCO facilities under the Kashagan field Experimental Program in 2006–2008 [MPE project, 2006; MPE project, 2007]; the number and intensity of emission sources determined the areas of pollution zone around offshore operation sites. Due to small height of stacks, maximum concentrations of pollutants emitted from these stacks distributed within 1–2 km from operation sites. The total area polluted by Kashagan East emission sources comprised from 3.0 to 6.0 km, and area polluted by emissions from some islands — from 1.0 to 2.5 km, i.e. this distance can be considered as maximum for assessment of impact from low emission sources.

In 2006–2007, well testing was conducted at A Island. Emissions from the flaring unit and equipment operation at other sites had more extended pollution area — 10 km on average. This may be explained by almost similar concentration of some pollutants at Level I and Level III stations. For example, the peak sulphur dioxide concentrations in autumn 2006 were almost similar both at stations near the facilities and at remote long-term observation stations (Figures 3.1 and 3.3).

In 2012–2016, the area of pollution was formed by fixed emission sources. The main pollutant emission sources during this period included [IEC Reports 2015, IEC Reports 2010–2014]:

- 2012 — installation operations, LQBs and barges at A and D Islands. Gross emission comprised approximately 3 thousand tones. The main contribution was made by sources used for installation operations, including LQBs and barges.
- 2013 — process equipment on A and D Islands, repair of wells, and flaring units. Gross emissions comprised over 12 thousand tones, the major part was emitted from flaring units of these islands.
- 2014 — repair operations on A and D Islands, flaring units, drilling operations on EPC islands. Gross emissions comprised

approximately 2.6 thousand tones. The main contribution was made by sources used during drilling operations on EPC islands.

- 2015 — repair operations on A and D Islands, drilling operations on EPC islands, construction operations at Oil field pipeline. Gross emissions comprised approximately 2.5 thousand tones; the main contribution was made by sources used during repair operations on D Island and pipelines construction.

- 2016 — processing equipment on A and D Islands, including operation of flaring units. Gross emissions comprised 16 thousand tones. The main contribution was made by flaring units on A and D Islands. выбросы факелов на островах А и D.

The size of pollution (impact) area, according to air pollutants dispersion modeling [Development project 2016, MPE standards projects 2012–2016] could be 7.0 to 20 km.

This means that theoretically, the impact from the offshore sources could expand not only to Level I stations but also to Level II stations and in some cases to Level III stations.

This pollution area could be caused by pollutant emissions from the flaring units on A and D Islands. This explains almost similar concentrations of main pollutants at Level I stations and at long-term observation stations (Figures 3.1–3.4). Concentrations of sulphur dioxide at Level I stations were slightly higher than those registered at the long-term observation stations. Concentrations of nitrogen dioxide and C_{12}-C_{19} group hydrocarbons were almost similar. The maximum values matched with the period of intensive flaring operations — 2013 and 2016. At the same time, the role of mobile emission sources shall not be lessened, i.e. different vessels, including support vessels of the Company. Their active movement within the territory of Kashagan East and presence of the same substances in emissions (sulphur dioxide, hydrocarbons) could form a pollution level at Level II and Level III stations regardless of fixed emission sources operation. For example, in 2015, volume of emissions from flaring units comprised approximately 18 tones; concentration of pollutants at these stations almost did not differ from the values registered in 2013 and 2016.

In addition, when analyzing the impact of operations on the atmospheric air, it is necessary to take into account complex physico-chemical processes occurring directly in the atmosphere. They are characterized by six main features [Aloyan, Piskunov, 2005; Marchuk, Aloyan, 2008]:

- Transfer of multicomponent gas impurities and aerosols along trajectories;
- Turbulent diffusion
- Photochemical transformation
- Kinetic processes of condensation
- Coagulation processes
- Chemical processes occurring in the gas and liquid phases, taking into account exchange on the gas-particle section.

If we do not go deeply into the dynamics of atmospheric processes, we can note two most important features that maximally affect the distribution of pollutants in the atmosphere. They are transfer of impurities along certain trajectories and turbulent diffusion. These features are associated with vertical and horizontal air temperature gradients.

THE MAIN REGULARITY IS THAT THE MORE TURBULENCE, THE FASTER AND FULLER THE DISPERSION OF POLLUTANTS.

When the vertical and horizontal temperature gradients increase, the wind speed also increases and, consequently, the conditions for dissipation of pollutants become more favorable.

Theoretical and practical studies have established that the axis of the flame with the pollutant rises and then descends again creating maximum at the upper boundary layer of the atmosphere (Figure 3.12) [Bezuglaya, 1983; Genikhovich, 1989; Genikhovich, Filatova, 2002; Genikhovich, etc., 2016]. However, at certain time, there may be long periods of weak air movement or complete calm. These situations occur most often in late spring and early autumn. With a weak convective, neutral or stable stratification of the turbulent flow, the axis of the flare rises and falls down

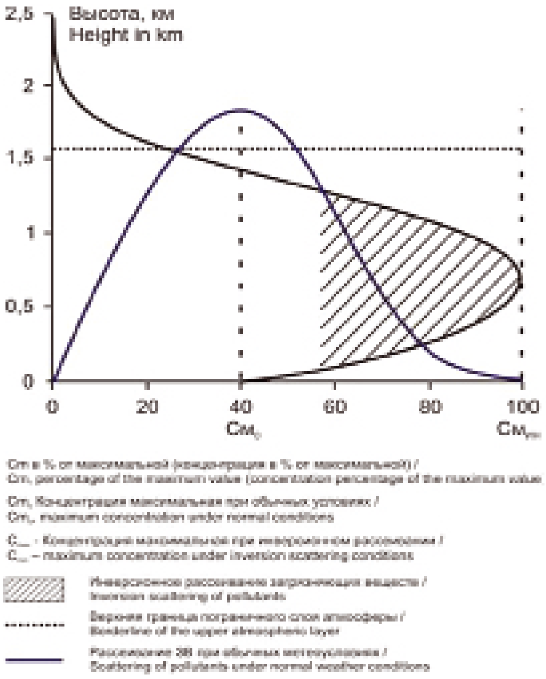


Figure 3.12 Correlation between the maximum ground level concentration (C) of pollutants and physico-chemical and meteorological processes in the atmosphere

practically with the same content of pollutants.

In these periods, the pollutants dispersion depends on inversion processes. They are characterized by a retention of pollutants inside or below the inversion layer due to a weak or complete absence of pollutants vertical dispersion. In such cases, pollutant emitted even from high sources can remain in the ground layer of the atmosphere.

These conditions can explain to some extent the behavior of oxide carbon in off-season periods, spring 2015 at Kashagan (Figures 3.2, 3.4), autumn 2014 at Aktote, Kairan and Kalamkas fields (Fig. 3.6 —3.11). In these periods, regardless of operational activity, peak concentrations of oxide carbon were observed at virtually all monitoring stations.

A certain influence of meteorological conditions was also observed at other production facilities in the North Caspian Sea region. For example, below are the results of the atmospheric air observations carried out at the Y. Korchagin field in 2016 (Russia) [Industrial Environmental Monitoring, Lukoil, 2016]. This is an oil and gas condensate field. It is located in the northern part of the Caspian Sea, 180 km from Astrakhan. The hydrocarbons production is carried out from two ice-resistant fixed platforms (LSP-1, LSP-2). The production facilities also include an offshore loading terminal (OTT) and an underwater oil pipeline.

Measurements of the state of atmospheric air were carried out under industrial environmental monitoring. During the observations period (from March to September), 160 measurements were taken.

According to available data, the concentration of pollutants in the ambient air in the area of ice-resistant fixed platform and offshore loading terminal did not exceed the maximum permissible value and detection limits established for the measurement techniques used (Table 3-1).

As shown by theoretical studies confirmed by field

Table 3-1 Results of measurements of the state of atmospheric air at the Y. Korchagin oil and gas condensate field production facilities in 2016

№	Pollutant	$MPC_{m.o.t.}$, mg/m³	Detection limit according to RD 52.04.186.89	Number of samples exceeding	
				Detection limit	$MPC_{m.o.t.}$
1.	Nitrogen oxide	0,4	0,031	0	0
2.	Nitrogen dioxide	0,2	0,024	0	0
3.	Sulfur dioxide	0,5	0,05	0	0
4.	Carbon oxide	5,0	0,75	0	0
5.	Suspended matter	0,5	0,26	0	0
6.	Soot	0,15	0,025	0	0

measurements, favorable weather conditions in a warm period provide a fairly fast and complete dispersion of pollutants in the atmosphere. And, on the contrary, inversion and other complicated physico-chemical processes in the off-seasons can create zones of increased pollutant concentrations, which are practically independent of operational activity.

As mentioned above, in general the level of impact on the ambient air from the Company's fields can be characterized as low. In order to prevent (minimize) negative impact in future, the following actions are recommended:

At Kashagan field: comply with the requirements of the Associated Petroleum Gas Processing Development Programme. Perform studies to improve the methods of gas utilization.

- Maintain fixed equipment in working condition; strictly follow the schedule of preventive maintenance in order to avoid potential cases of gas release to the flare.
- During repair and maintenance operations, use, if possible, environmentally safe or minimally polluting equipment.

At Aktote, Kairan, Kalamkas fields: strictly adhere to the operational monitoring schedule, which includes emissions monitoring and impact monitoring. If any negative facts are found, immediate actions shall be taken to eliminate sources of pollution.

- Perform a regular monitoring of the technical condition of not used drilling equipment in order to ensure its safe condition.

Sea vessel activities: organize sea vessels navigation along certain routes to avoid irrational movements and, if possible, long-term parking with running engines.

- Carry out regular monitoring of their technical condition
- Strictly observe the schedule of major and routine repairs in order to ensure trouble-free operation of engines and other vessel equipment.

Conclusions

Thus, all observed pollutant concentrations at Kashagan, Aktote, Kairan and Kalamkas fields at all levels stations were generally below the $MPC_{m.o.t.}$ The highest concentrations of sulfur dioxide, nitrogen oxide and hydrocarbons were of intermittent nature. This was due to both seasonal changes in the atmosphere and the impact of operations at the fields at that time. A certain impact of operations was observed at Kashagan field Level I stations. At Aktote, Kairan and Kalamkas fields, impact from various types of vessels was observed. This is confirmed by the fact that the maximum pollutant concentrations were recorded in the navigation period.

The impact of well tests on the state of the ambient air can be assessed as local. It is limited to a 10–kilometer zone stretching from the flaring unit, and the concentrations do not exceed the $MPC_{m.o.t.}$ value. The fluid flaring process is quite efficient, as evidenced by absence of soot emissions in the area impacted by this process.

At the same time, increase of carbon oxide concentrations was noted almost at all stations, including baseline stations. Moreover, maximum concentrations of carbon oxide were recorded outside the area of impact of the facilities under operation or under construction. For example, it was observed at long-term monitoring stations EB-14 and EB-26 located on the southeastern and western borders of Kashagan field. In order to explain these carbon oxide concentrations, a wider range of observations has to be carried out in different climatic seasons.

4. QUALITY OF SEA WATER

The environmental baseline and monitoring surveys (offshore environmental surveys) were carried out in the framework of the 2006–2016 environmental monitoring programs developed on the basis of the legislative documents of the Republic of Kazakhstan including the "Rules for Organization and Performance of Environmental Compliance Monitoring during Petroleum Operations in Kazakhstan Sector of the Caspian Sea" [Rules, 2012, 2014]. The analytical overview of the offshore environmental monitoring results is presented by the Company's Contract Areas: Kashagan field, Kalamkas-Sea field (Kalamkas), Kairan field, Aktote field and Oil field pipeline.

MONITORING STATION NETWORK IS THE DENSEST IN KASHAGAN AND OBSERVATIONS WERE CONDUCTED THERE ON A REGULAR BASIS (FROM 2006 TO 2012 IN SPRING AND AUTUMN, SINCE 2013 IN SPRING, SUMMER AND AUTUMN).

In other areas the number of sampling stations was less and the observations were not continuous. For example, no observations were conducted at Kairan and Aktote fields from 2006 to 2011 (see Annex 1). Sampling of sea water was carried out from the surface and near-seabed layers. In parallel with the sampling, water parameters were measured.

Offshore environmental surveys were carried out by the Company in accordance with the "Guidelines for Field Work: Baseline Studies and Environmental Impact Assessment Study". GE00.HSE.H30.PR.0002.00 Rev. 03. Agip, HSE Department, 2009, in compliance with "12 Golden Rules" for labor safety. Sea water samples were taken according to ST RK GOST R 51592-2003.

Concentrations of some pollutants were compared with maximum permissible concentrations (MPC) for fishery water bodies [MPC Summary List, 1990].

To assess the impact of man-caused factors, the values of physical-chemical parameters of water and concentrations of pollutants recorded during long-term monitoring in the Contract Areas waters at environmental monitoring stations [Monitoring Reports, 2006–2016] were compared with the values recorded at the stations of integrated offshore surveys to assess the state of biological resources of Kazakhstan part of the Caspian Sea (independent survey, further referred to as the integrated offshore survey) in the period 2010-2016. [Biological Substantiation, 2010–2015, 2016]. The area of integrated offshore surveys covers the whole Kazakhstan part of the North Caspian Sea.

Hydrophysical and hydrochemical measurements were taken with use of Horiba U-10 probe in the surface and seabed (where applicable) layers. Samples of water for laboratory analysis were collected using a bathometer. Several water samples were placed in a common container. The combined sample was immediately filtered for analysis through filters of 0.45-micron porosity, then the filtered water was put into special bottles for collection and storage.

Annex 3, Table A1-1 shows the methods and techniques for determining the seawater parameters [Monitoring Reports, 2006–2016].

The following physical parameters were determined in situ at all survey stations: temperature, salinity, pH, turbidity, transparency, dissolved oxygen in water.

Temperature

At the stations of environmental monitoring, the average temperature in the period under survey was in the range of -17.1–20.6 °C in spring, 24.3–27.0 °C in summer, and 10.1–15.8 °C in autumn.

HIGH WATER TEMPERATURES WERE RECORDED IN SUMMER 2015: THE MAXIMUM VALUE WAS RECORDED AT KASHAGAN, NEAR D ISLAND - 31.2 °C.

According to observations, the average values in the areas under study range from 16.2 to 20.1 °C.

At the integrated survey stations [Biological Substantiation, 2010–2015, 2016], the average long- term water temperatures in summer (24.5–27.5 °C) were very close to the results of monitoring observations, and the autumn temperatures were significantly higher (22.2–22.6 °C). The difference in recorded autumn temperatures is due to observation periods, sometimes environmental monitoring completed in November.

The difference in temperatures of the surface and near-seabed layers of water during summer and autumn periods is practically insignificant, and in summer the temperature is in the range of 0.3–0.7 °C, in autumn - 0.2–0.5 °C. The major difference in temperatures is in spring - up to 1.9 °C. Figure 4.1 below shows the distribution of temperature in the water of the study zones in 2006–2016

Salinity

The salinity of sea water depends on the inflow of the continental rivers and can vary depending on the direction of winds and currents prevailing in the northern part of the Caspian Sea. According to integrated offshore surveys, the average salinity value at the surface was 6.9 ‰, at the seabed - 7.04 in summer, while in autumn it was 6.21 ‰ both at the water surface and in seabed layers.

The average salinity values recorded at environmental monitoring stations were as follows: the minimum was in the area of Oil field pipeline - 5.64 ‰; the maximum was in the area of Kalamkas field - 7.32 ‰. At the integrated offshore survey stations, the maximum values were recorded in summer 2011 (up to 11.10 ‰); and at environmental monitoring stations (Oil field pipeline) it was 16.1 ‰ in autumn 2011. The distribution of salinity at environmental monitoring stations is shown in Figure 4.2.

Transparency and turbidity

The water area of the Northern Caspian Sea is characterized by low water transparency - 0.4–2.6 m in spring and 0.3–2.8 m in summer. The average values are 1.2–1.4 and 1.3–1.7 m respectively [Atlas , 2014]. The turbidity and transparency of water are very dynamic indicators in shallow waters and can change both under the influence of storms, development of phytoplankton, and due to anthropogenic activity (movement of ships in shallow water). The average values of water transparency recorded during integrated offshore surveys were within 0.82–1.35 m through the entire observation period.

During the 2006–2016 monitoring, the average transparency values in the area of the surveyed areas were equal to 0.42–1.11 m. The distribution of transparency and turbidity in the waters of the study zones in 2006–2016 are shown in Figure 4.3.

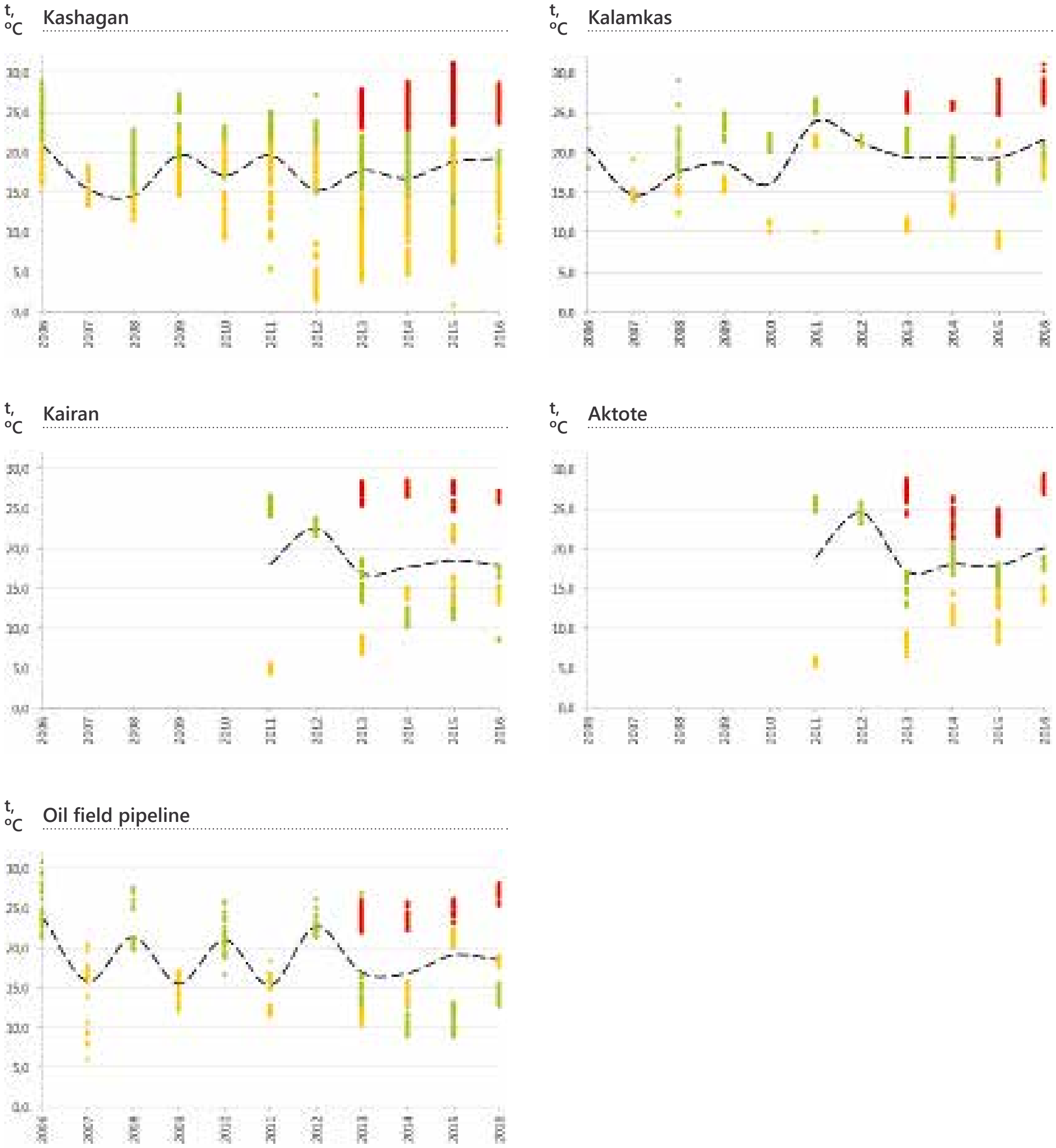
The integrated offshore surveys showed that the average value of turbidity fluctuated during the summer season in the range of 3.23–46.18 NTU and in autumn - 36.03–86.04 NTU. The monitoring surveys recorded the average values of turbidity in following ranges: in spring - 40.43–96.79, in summer - 19.92–104.48, in autumn - 56.43–74.81 NTU.

The influence of storms can explain the maximum values of the water turbidity. The maximum values of this parameter in integrated offshore surveys were recorded in autumn 2014 when the value was 222 NTU.

The maximum values of 562 and 237 NTU were recorded in autumn 2007 at Kashagan and Kalamkas fields respectively; 402 NTU was in spring 2014 at Kairan, and 555 and 386 NTU in summer along the Oil field pipeline and Aktote field respectively. As a rule, the maximum values of turbidity were recorded in the seabed layer of sea water, since this parameter depends on the depth and nature of the surface layers of bottom sediments.

Hydrogen indicator pH

The pH values are mainly determined by the carbonate equilibrium throughout the entire North Caspian Sea, and fluctuate in the alkaline range. According to the RSE Kazgidromet, in 2006-2016, the pH values in the North Caspian Sea were in the range of 6.9–9.9 [Kazgidromet



Note: *spring period;* *summer period;* *autumn period; dotted line = average values.*

Figure 4.1 Distribution of water temperatures in 2006–2016

Bulletin, 2006–2016]. According to integrated offshore surveys, the maximum values up to 9.98 were recorded in 2011, 2013 and 2014. The average values in the summer period ranged from 8.39 to 9.2, in the autumn period - from 8.41 to 8.62.

According to the environmental monitoring data, the average pH values in all surveyed areas were in the following ranges: in spring - 8.34–8.59; in summer - 8.45–8.59; in autumn - 8.46–8.61 (Figure 4.4). High values were recorded in the surface layers in spring and autumn: the development of photosynthetic activity of the aquatic flora slowed down due to low temperatures, which shifted the carbonate equilibrium towards reduction of carbon dioxide and increase in pH value.

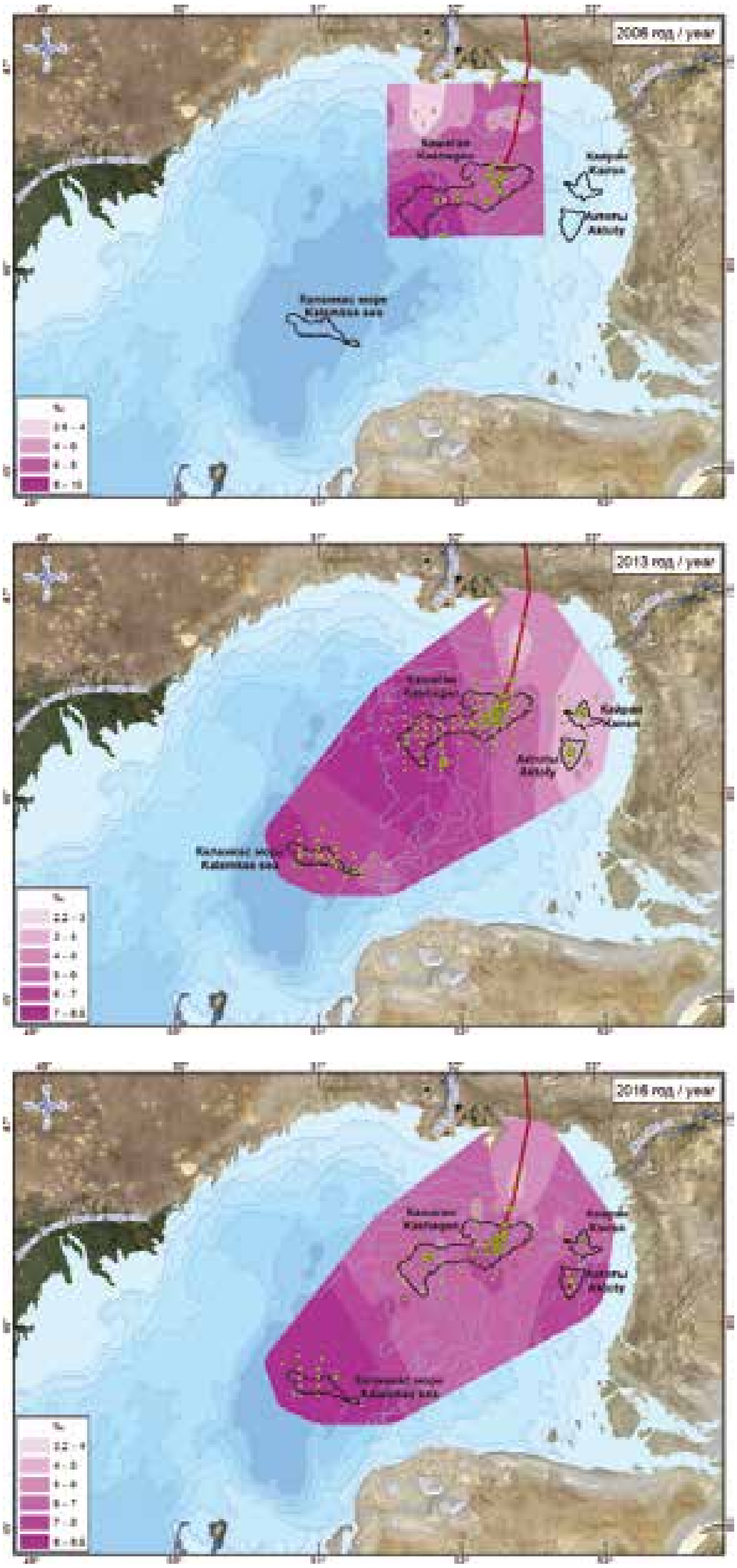
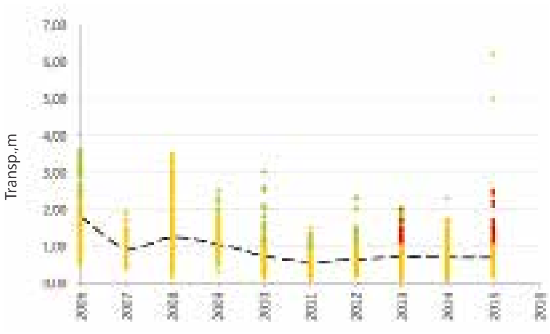


Figure 4.2

Distribution of salinity in 2006 (spring), 2013 (autumn), and 2016 (summer)

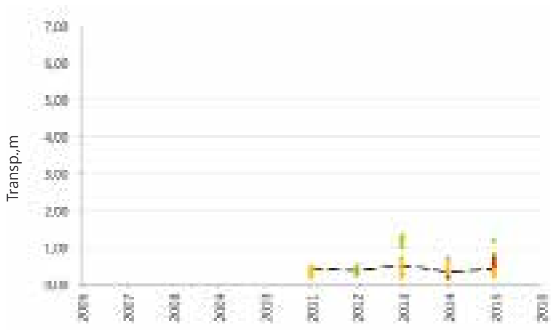
Kashagan



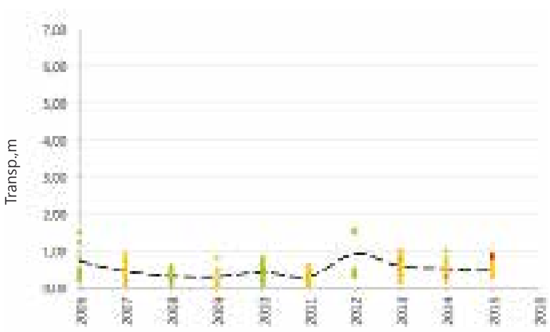
Kalamkas

Kairan

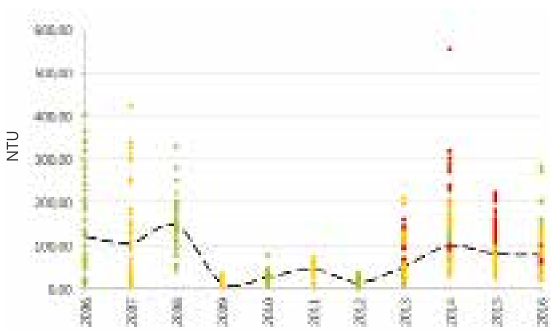
Aktote



Oil field pipeline



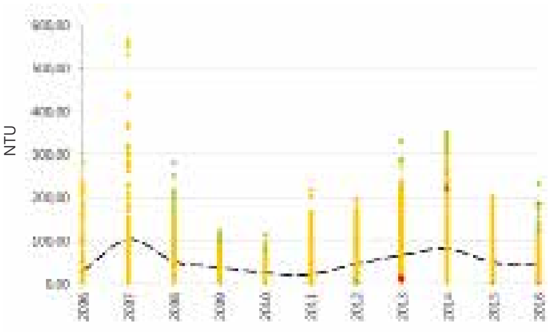
Oil field pipeline



Note: *spring period;* *summer period;* *autumn period; dotted line = average values.*

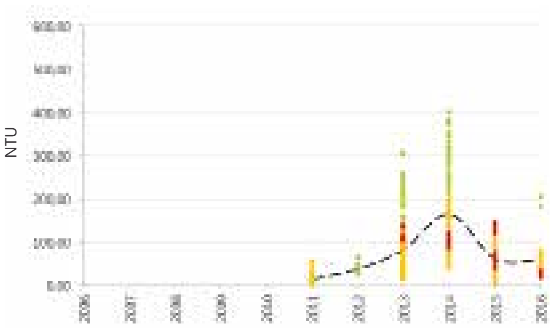
Figure 4.3 Distribution of water transparency and turbidity in 2006-2016

Kashagan

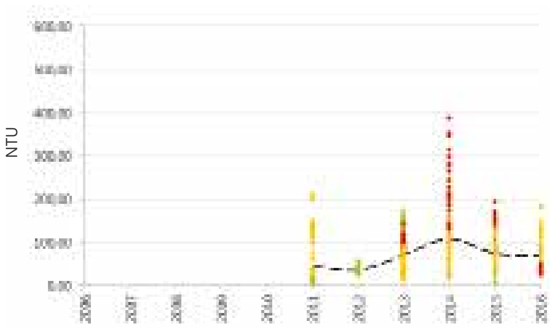


Kalamkas

Kairan



Aktote



Note: *spring period;* *summer period;* *autumn period; dotted line = average values.*

Figure 4.3 Distribution of water transparency and turbidity in 2006-2016

Dissolved oxygen

The solubility of oxygen in water rises with decrease in its temperature, so the content of dissolved oxygen is mainly determined by the temperature of water. Oxygen is a gas that relatively poor dissolves in water. At the temperature of 20 °C, about 9 mgO_2/dm^3 oxygen dissolves in the water.

The integrated offshore surveys indicated the following ranges in the content of oxygen dissolved in water: in spring - 7.64–8.75 mgO_2/dm^3, in autumn - 7.92–8.82 mgO_2/dm^3. The content of oxygen in the surface and the seabed layers was homogeneous.

According to the monitoring surveys carried out earlier in 1996–2005 [Reports, 1993–2006, MPC Summary List, 1990], the average values of dissolved oxygen were in the following range: 9.10–12.50 mgO_2/dm^3 in spring and 8.00–11.30 mgO_2/dm^3 in autumn.

It should be noted that the average content of oxygen dissolved in the water in 2006–2016 study period was recorded at levels not lower than the permissible level, i.e. at least 6 mgO_2/dm^3 (Figure 4.5). Separate observations showed low concentrations of dissolved oxygen (the minimum value of 4.26 mgO_2/dm^3 at Aktote field).

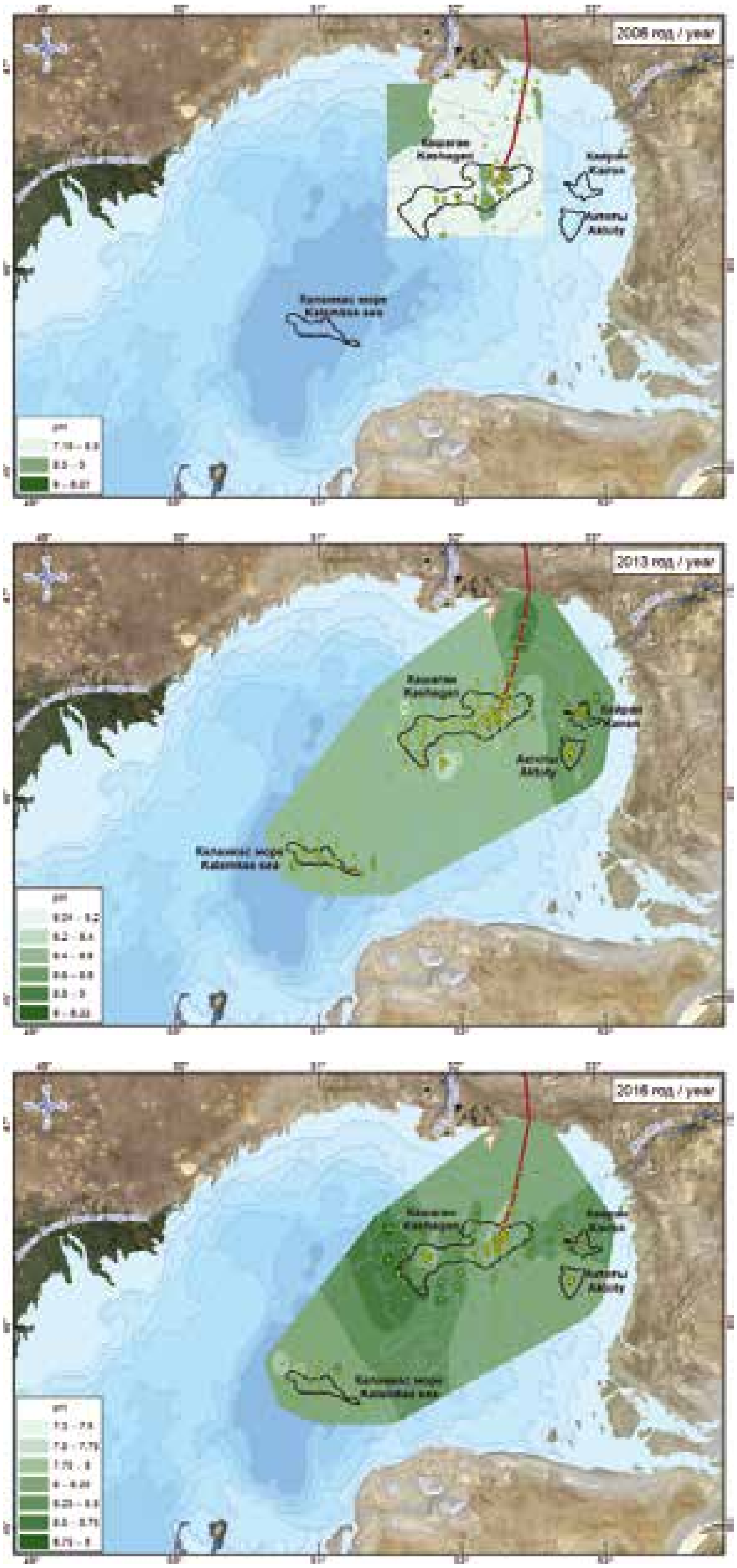


Figure 4.4

Distribution of pH values in 2006 (spring), 2013 (autumn) and 2016 (summer)

Biogenic compounds

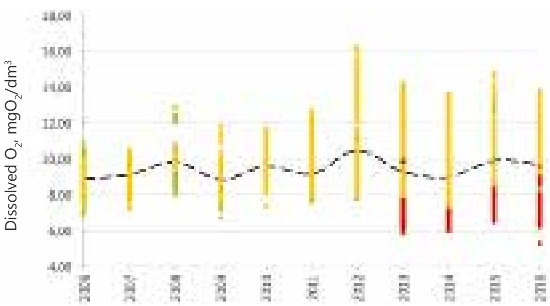
Samples of sea water were analyzed for the content of the dissolved nutrients of the nitrogen group: ammonium nitrogen (N-NH_4), nitrogen nitrite (N-NO_2), nitrogen nitrate (N-NO_3) and total nitrogen (Ntotal). In addition, dissolved phosphorus was also analyzed from spring 2006 to spring 2009 and later total phosphorus (Rtotal) was analyzed till 2016.

Shallow depths and active mixing of water create conditions for a homogeneous distribution of nutrients components in vertical direction. The nutrients stratification in sea water is not evident in the areas under consideration, some signs of vertical differentiation were observed at Kalamkas field where higher levels of ammonium nitrogen were observed in the seabed horizon. An inverse relationship was traced at Kashagan with a slight predominance of mineral forms of nitrogen and phosphorus in the water surface layer.

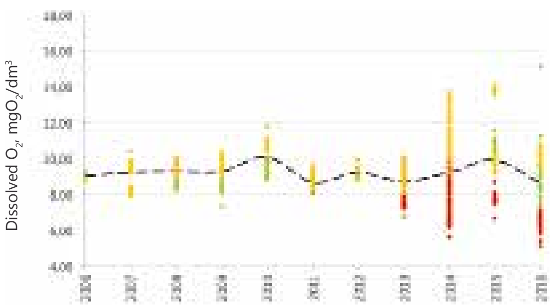
Ammonia nitrogen.

In 2006–2016, the range of ammonia nitrogen (N-NH_4) content in water basin under consideration

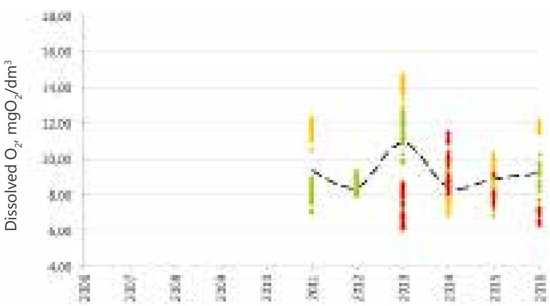
Kashagan



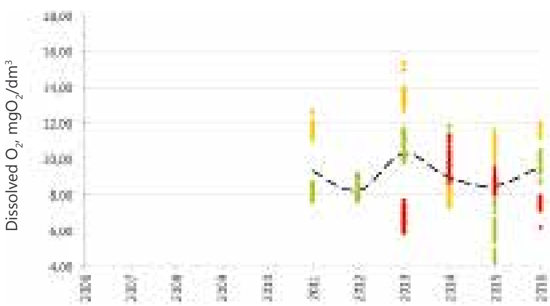
Kalamkas



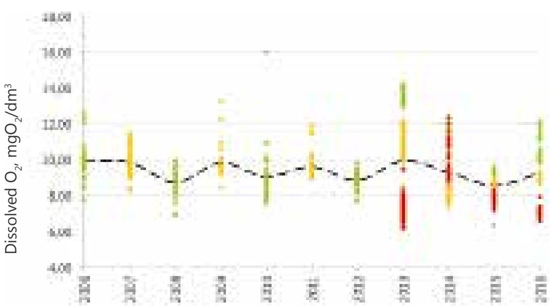
Kairan



Aktote



Oil field pipeline



Note:

- *spring period;*
- *summer period;*
- *осенний период; пунктирная линия – средние значения.*

Figure 4.5 Distribution of dissolved oxygen in 2006–2016 was from < 0.004 to 1.06 mg/dm^3, in 1993–2006 – from 0.01 to 0.16 mg/dm^3 [Atlas, 2014], and in 2010–2016 - from 0.01 to 0.23 mg/dm^3 [Biological Substantiation, 2010–2015, 2016].

Almost 97 % of determined concentrations were in the range from below 0.01 to 0.3 mg/dm^3; 0.3–0.5 mg/dm^3 concentrations made up 2 %; over 0.5 mg/dm^3 made up 1 %. Episodic concentrations of N-NH_4 equal to 1.0 mg/dm^3 were recorded at Kashagan (2010) and Aktote (2011). The annual median N-NH_4 levels increased from 0.021 to 0.15 mg/dm^3 between 2006 and 2010; in 2011–2012 they did not exceed 0.3 mg/dm^3, then gradually decreased to 0.020 mg/dm^3 starting from 2013, and returned to the level of 2006 in 2016. According to integrated offshore surveys, the average values of N-NH_4 were high in 2010 (0.101 mg/dm^3), however, in 2011–2012 they were below the detection limit. In 2013–2015, the average concentration ranged from 0.01 to 0.07 mg/dm^3. In 2016, the average concentration was 0.02 mg/dm^3, at many stations it was lower than the method detection limit [Biological Substantiation, 2010–2015, 2016].

In spring 2006, higher concentrations of N-NH_4 (0.05–0.07 mg/dm^3) were recorded at Kashagan isthmus; in autumn 2009, N-NH_4 concentration spots were found in the vicinity of islands EPC3, EPC2, A and D Islands and at Kashagan neck. The maximum values were recorded at the following stations: PLA5 in 2011, IPEPC3-HUB2 in 2012 and EPC4 in 2013. The concentrations of N-NH_4 in the range 0.16–0.31 mg/dm^3 were recorded at stations KAL5NW, KAL5-03, KAL5-05 (2010) and KALW/EC (2014) in Kalamkas field.

In the water area of the Oil field pipeline, the N-NH_4 concentration range was not generally recorded from the shallow coastal zone transect (NP06) up to transects located further offshore. In some years, decrease of N-NH_4 in the direction of deeper depths was more evident, however, often it was interrupted by chaotic peaks, with high levels of N-NH_4 recorded in 2013–2014 at stations NP04-NP05 and especially at station NP06, with the average annual N-NH_4 concentration of 0.21 mg/dm^3 in 2013.

At Aktote field, the maximum annual average level of N-NH_4 was recorded in 2011 and made up 0.37 mg/dm^3, in 2013 it dropped to 0.08 mg/dm^3. The concentrations of N-NH_4 at station AKT-600/245 were in the range of 0.07–0.66 mg/dm^3, while at other monitoring stations it did not exceed 0.03–0.05 mg/dm^3.

At Kairan field, the variation in the concentration of N-NH_4 was significant, especially in 2013 (up to 0.117 mg/dm^3) with the average level of 0.04 mg/dm^3.

The multi-year median levels of N-NH_4 at Kashagan made up 0.04 mg/dm^3, in other areas -0.03 mg/dm^3. The slightly higher multi-year N-NH_4 level at Kashagan is due to locally formed zones, which were predominantly observed in 2006–2010. The distribution of ammonium nitrogen in seawater is shown in Figure 4.6.

Seasonal long-term levels of N-NH_4 recorded both in spring and autumn are quite close in the monitoring areas. No stable seasonal dynamics of the N-NH_4 content has been revealed in individual years. At the same time, in spring seasons, one can see higher content of N-NH_4 at Kashagan (0.044 mg/dm^3), and lower content (0.030 mg/dm^3) at Kalamkas and offshore sections of the Oil field pipeline. In spring periods, a significant variability of N-NH_4 distribution areas is observed in coastal shallow zones of Kairan and Aktote fields.

In autumn, the range of N-NH_4 fluctuations decreased, the levels became even with the values of 0.030 mg/dm^3 at Kairan, Aktote, while further in the sea in the area of Oil field pipeline (0.040 mg/dm^3) and at Kalamkas (0.032 mg/dm^3) they still remained at the same level, probably due to minimum values.

Nitrogen nitrogen.

In 2006–2016, the content of nitrite nitrogen (N-NO_2) was in the range of 0.0001– 0.066 mg/dm^3, in 1993–2006 it ranged from 0.001 to 0.005 mg/dm^3 [Reports, 1993–2006], and according to data recorded during integrated offshore surveys, it was in the range of 0.004– 0.01 mg/dm^3 [Biological Substantiation, 2010–2015, 2016].

The concentrations of N-NO_2 were recorded in the range of 0.008–0.01 mg/dm^3 near the EPC islands in autumn 2013 as well as near the islands DC01, DC04 in spring of 2014 (Fig.4.7). The average long-term N-NO_2 content in the eastern part of the North Caspian Sea is 0.002–0.005 mg/dm^3. In spring, the concentrations of N-NO_2 are minimal in the Northern Caspian Sea: in the eastern part of the sea, at the Ural (Zhayk) River pre-estuary area they are 0.006 mg/dm^3 and 0.001 mg/dm^3 at the Ural Furrow. In October-November, the N-NO_2 concentrations decreased compared with their summer level up to 0.002–0.003 mg/dm^3 [The Caspian Sea.SPb, 1996].

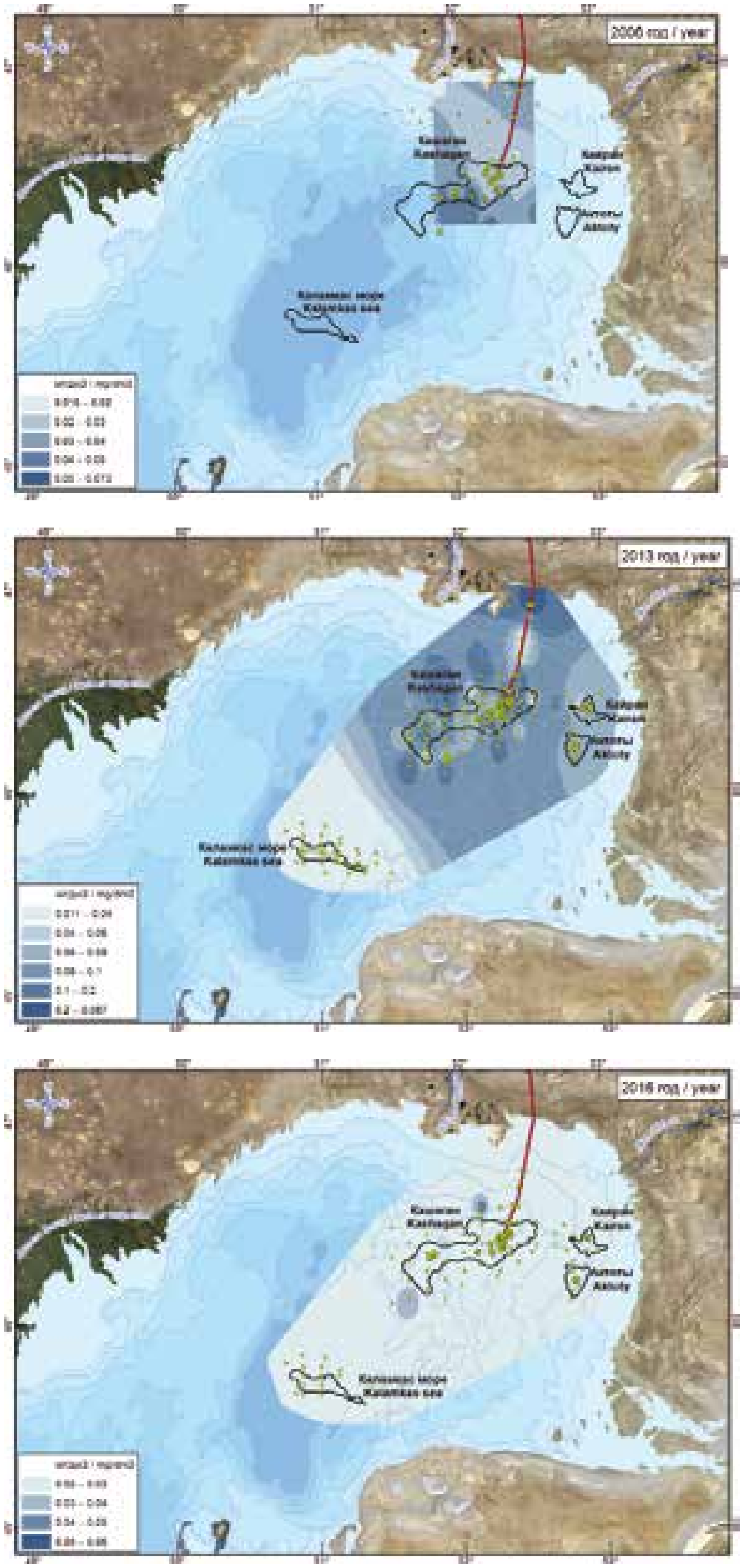


Figure 4.6

Distribution of ammonium nitrogen in 2006 (spring), 2013 (spring) and 2016 (summer)

According to the results of 2015 observations [Yearbook, 2003, 2015–2016], in the central and western parts of the shallow-water North Caspian Sea, the average concentrations of $N\text{-}NO_2$ ranged from 0 to 0.003 mg/dm³, on average 0.00058 mg/dm³ and with peaks equal to 0.135 mg/dm³.

In 2006–2016, the average $N\text{-}NO_2$ concentrations were as follows: in spring - 0.0020 mg/dm³, in autumn - 0.0031 mg/dm³, in summer - 0.0046 mg/dm³. The 2006–2016 monitoring surveys showed no content of $N\text{-}NO_2$ in most samples.

According to integrated offshore surveys, the $N\text{-}NO_2$ concentrations recorded from 2010 to 2012 were also below the detection limit. Starting from 2013, the average concentration increased from 0.003 mg/dm³ to 0.008 mg/dm³ in 2016. The maximum concentrations recorded in 2016 were 0.010 mg/dm³ [Biological Substantiation, 2010–2015, 2016].

Nitrate nitrogen

In 2006–2016, the range of nitrate nitrogen ($N\text{-}NO_3$) content in water area under study was in the range of < 0.005 - 8.6 mg/dm³ (from 0.02 to 0.15 mg/dm³ in 1993–2006).

According to the 2010–2016 integrated offshore survey, the content of nitrate nitrogen ($N\text{-}NO_3$) was in the range of 0.015–1.59 mg/dm³. During the integrated offshore survey, low average concentrations of $N\text{-}NO_3$ were recorded in 2011 and 2015 (0.099 mg/dm³ and 0.021 mg/dm³, respectively). In the other monitoring period, the average concentrations were 0.5–0.81 mg/dm³ [Biological Substantiation, 2010–2015, 2016]. Almost 82 % of concentration values were in the range of < 0.025–0.40 mg/dm³; in the other samples the concentrations were above 0.4 mg/dm³.

Between spring 2006 and spring 2009, the range of this parameter fluctuation in the water area under survey tended to the average annual (1961–1983) content of $N\text{-}NO_3$ in the eastern part of the North Caspian Sea, the value of which ranges in spring from 0.0045 to 0.012 mg/dm³ and in autumn - from 0.012 to 0.023 mg/dm³.

In 2006–2010, higher concentrations of $N\text{-}NO_3$ were mostly recorded at Kashagan field near islands EPC2, EPC3, IPEPC3-HUB2 and PLA5 with concentrations above 0.5 mg/dm³ and in the Oil field pipeline area, i.e. in low depth areas. Between 2011 and 2013, $N\text{-}NO_3$ concentrations were in the range of 0.015–0.93 mg/dm³, with a single peak of 50.86 mg/dm³ (5.6 MPCm.o.t.) recorded at station NP-F11A in autumn 2011. At the stations located at remote distances from the islands, $N\text{-}NO_3$ concentrations were in the range 0.019–0.87 mg/dm³. In Kalamkas area at station G in the spring season, $N\text{-}NO_3$ content was 0.14–0.16 mg/dm³, while in autumn it was 0.52 mg/dm³.

In 2013 (spring, summer), the concentrations of $N\text{-}NO_3$ were in the range of 0.04–0.94 mg/dm³. During that period, relatively high concentrations were recorded in the vicinity of the islands EPC2, EPC3, DC04, DC10, PLA5, at infield pipelines (IP EPC3 -HUB2), as well as at some stations in Kalamkas (2L/KAL and 3L/KAL-01).

High concentrations were also recorded at stations of integrated offshore studies in autumn 2013 with values in the range of 0.96–1.33 mg/dm³ [Biological Substantiation, 2010–2015, 2016].

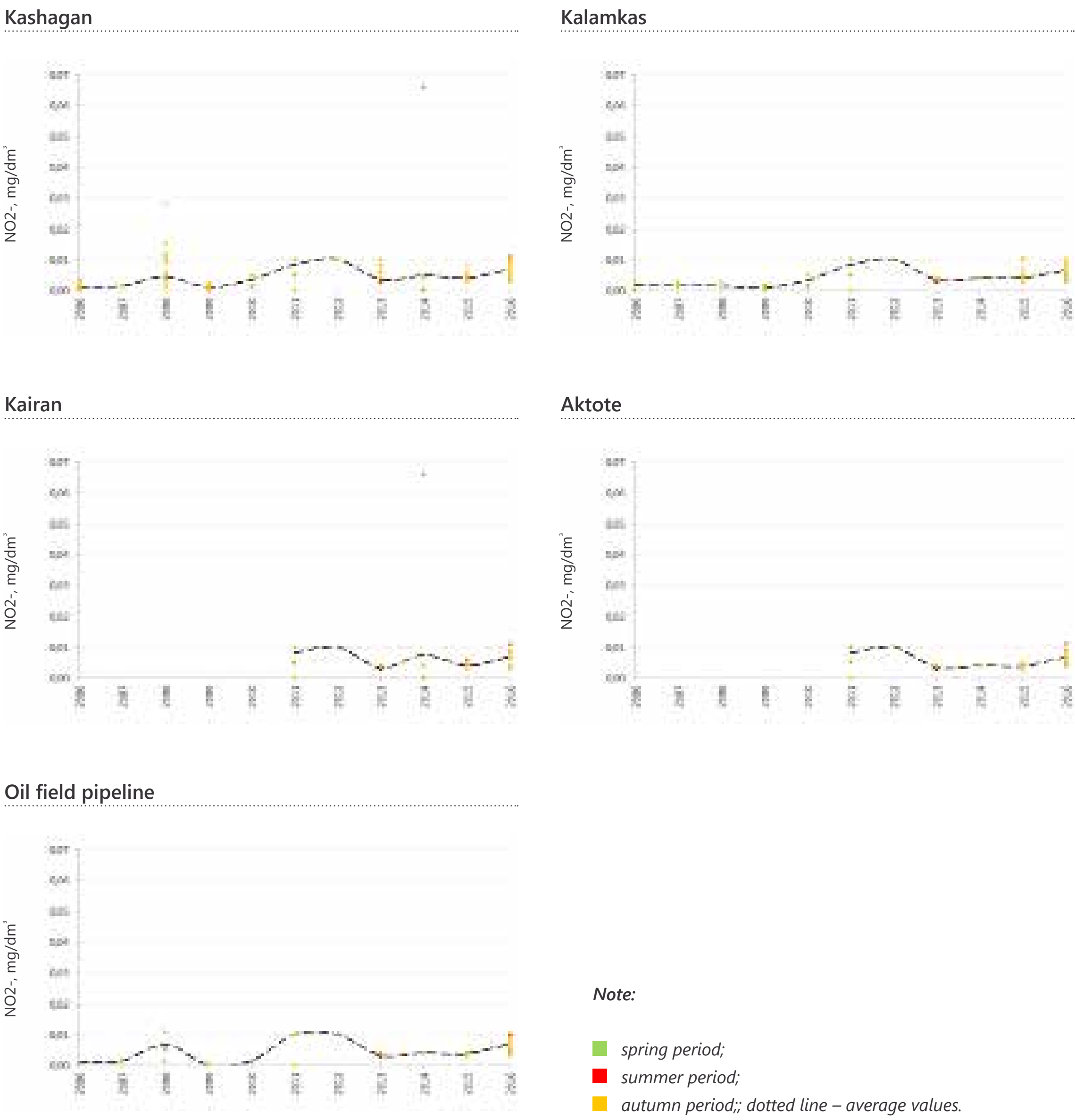
In 2015 spring and summer seasons at the environmental monitoring stations, the concentrations of $N\text{-}NO_3$ were below 0.015 mg/dm³, however, in autumn they increased to 0.2–1.2 mg/dm³. In 2016 N NO_3 concentrations were in the range of 0.1–0.6 mg/dm³ and relatively higher concentrations were observed at stations IP1, IP2, KRN/245. In other years of the 2006–2016 period, the long-term median $N\text{-}NO_3$ levels ranged from 0.14 mg/dm³ to 0.3 mg/dm³ (Figure 4.8).

Spatial distribution of nitrate nitrogen shows the following patterns: presence of high concentrations in zones with low depths, especially in the zone with depths up to 2 m, as well as lower concentrations in the direction from north to south.

Total nitrogen.

According to 2010–2016 integrated offshore surveys, the range of total nitrogen content in the Caspian Sea was from 0.005 to 4.2 mg/dm³ [Biological Substantiation, 2010–2015, 2016]. According to the results of environmental monitoring carried out by the Company in 2006–2016 the range of this value was from < 0.003 to 16.5 mg/dm³ [Monitoring Reports, 2006–2016], and from 0.06 to 4.39 mg/dm³ in 1993–2006.

Environmental monitoring data collected from 2006 to spring 2007 shows that the total nitrogen content was 0.4–4.0 mg/dm³, in autumn 2007 it was < 0.003 mg/dm³. In spring seasons 2008 and 2009, the concentration of total nitrogen also did not exceed 0.003 mg/dm³. In autumn 2009,



Note:

- *spring period;*
- *summer period;*
- *autumn period;; dotted line – average values.*

Figure 4.7 Distribution of nitrites in 2006–2016

the concentrations increased by 2–3 orders of magnitude, amounting to 0.8–10 mg/dm³. There were no local zones of increased concentrations of total nitrogen. In autumn 2010, in most cases, the concentrations of less than 0.01 mg/dm³ prevailed.

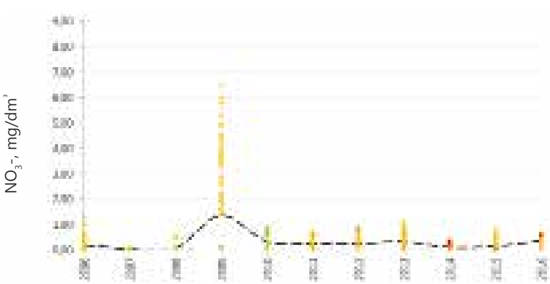
In 2011, the content of total nitrogen at Kalamkas, as a rule, did not exceed 0.20 mg/dm³. At the integrated offshore survey stations, this parameter value was up 0.1 mg/dm³ [Biological Substantiation, 2010–2015]. In 2012, total nitrogen level at Aktote and Kairan increased to 0.60 mg/dm³, and in 2013 at Kalamkas it was 0.78 mg/dm³. In 2013, at some monitoring stations of Level II and Level III, predominantly at Kashagan West, the concentrations of total nitrogen shifted to the range of 0.4–0.6 mg/dm³, and at some stations reached 1.0 mg/dm³. In autumn, at certain stations, the maximum concentrations were recorded up to 1.7–2.26 mg/dm³. The maximum average values were also recorded at the integrated offshore survey stations in 2012 and in autumn 2013 (2.48 and 1.29 mg/dm³, respectively) [Biological

Substantiation, 2010–2015, 2016]. Low levels of total nitrogen were registered in 2014–2015 for all the surveys conducted at that time [Biological Substantiation, 2010–2015, 2016]; during that period the average annual values of total nitrogen in the areas under survey were mostly limited to 0.19 mg/dm^3.

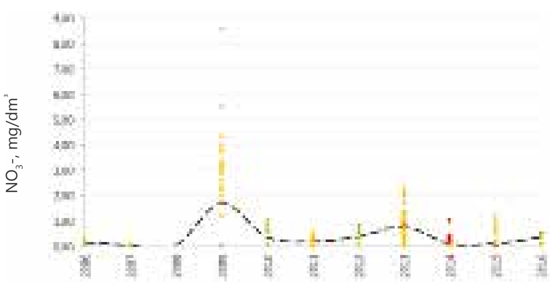
In 2015–2016, the concentrations of total nitrogen in Kalamkas water area were in general below the level of analytical detection, mostly < 0.004 mg/dm^3. In that period, concentrations of 0.6–1.2 mg/dm^3 were mainly recorded in the southern part of Kalamkas field.

Despite the diversity of the data, it is possible to outline some specific features. In 2016, the average annual (average for 3 seasons) level of nitrogen content was 0.5 mg/dm^3. These values are quite close to the values recorded in 2015 in the shallow part of the North Caspian Sea [Yearbook, 2003, 2015–2016], with average values of 0.264 and 0.554 mg/dm^3 in 2 sections and with peak values of 0.895 mg/dm^3 and 1.324 mg/dm^3.

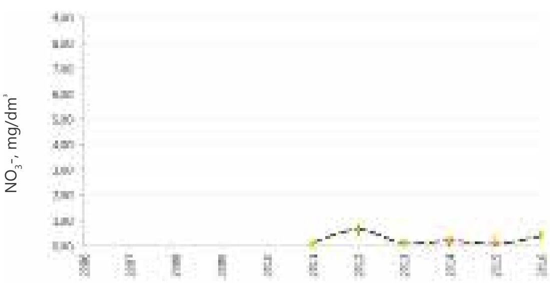
Kashagan



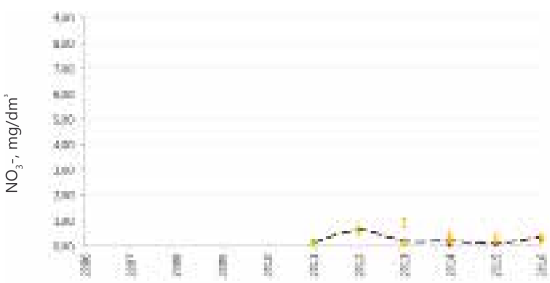
Kalamkas



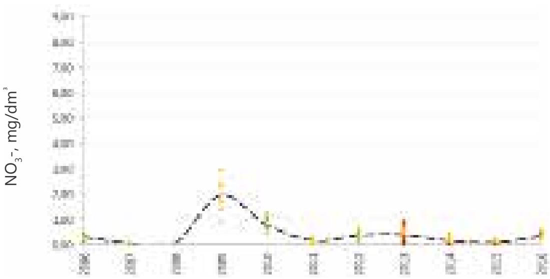
Kairan



Aktote



Oil field pipeline



Note:

- *spring period;*
- *summer period;*
- *autumn period; dotted line – average values; NO_3 .mg/dm^3*

Figure 4.8 Distribution of nitrates in 2006–2016

Average annual spring levels of total nitrogen are much higher in the Oil field pipeline water area, but they decrease towards Kalamkas, Aktote, Kairan, therefore, Kashagan occupies an intermediate position in this row. In autumn seasons, the Oil field pipeline area in terms of total nitrogen content takes still a leading position while Kairan and Kashagan refer to the areas with a relatively low content of total nitrogen.

THE OBTAINED RESULTS INDICATE DIFFERENCES IN THE INTENSITY OF PHOTOSYNTHESIS PROCESSES.

According to available monitoring data, these processes are more intensive in the Oil field pipeline water area in spring, which leads to the transformation of nitrogen and phosphorus mineral forms into organic. In Kalamkas area with salinity increase, the intensity of these biological processes decreases.

Total phosphorus

In 2006–2016, the range of total phosphorus content in the water area was from < 0.0025 to 1.16 mg/dm^3, while it was in the range of 0.004 to 0.14 mg/dm^3, according to integrated offshore surveys of 2010–2016 [Biological Substantiation, 2010–2015, 2016]. This element was determined starting from autumn 2009, earlier, in the period from 2006 (spring) to 2007 (summer), mineral phosphorus miner was determined and phosphates (PO_4) were determined in the period from 2007 (autumn) to 2008 (spring).

In 2006–2010, the content was in the range from below 0.002 to 0.059 mg/dm^3. Higher concentrations were recorded in the Oil field pipeline area (up to 0.03 mg/dm^3). In 2010, during the integrated offshore survey, total phosphorus concentrations were recorded up to 0.579 mg/dm^3 [Biological Substantiation, 2010–2015].

In the period 2011–2016, the total phosphorus content was determined regularly, its content was in the range of 0.0025–1.16 mg/dm^3 averaging 0.011 mg/dm^3.

The average annual concentrations of total phosphorus in the areas under study were rather homogeneous in general, except for some years. The variability was recorded in 2013 and 2015 when the total phosphorus content reached the value of 0.5 mg/dm^3 at some stations.

In 2013, a low content of total phosphorus was recorded at Aktote (0.009 mg/dm^3) and Oil field pipeline (0.013 mg/dm^3), in 2015 – at Kairan (0.005 mg/dm^3). At Kashagan (2011–2016), the average annual concentrations of total phosphorus were in the range of 0.005–0.010 mg/dm^3. In some years (as a whole for the year), higher total phosphorus concentrations were recorded in the Oil field pipeline coastal section (NP06 0.036 mg/dm^3), as well as in the zones surrounding Kashagan and Kalamkas stations - 0.110–0.488 mg/dm^3. In Aktote and Kairan areas, the phosphorus concentrations ranged from above 0.02 mg/dm^3 to 0.35 mg/dm^3.

If we review the results of long-term spring environmental monitoring (periods of active development of phytoplankton), we get a generally inexpressive picture of the total phosphorus distribution with a slightly higher concentration recorded at Kairan.

According to Roshydromet [Yearbook, 2003, 2015–2016] in 2015 (March-November) in the shallow-water of Russian sector in the North Caspian Sea at close to shore stations, the total phosphorus concentration was in the range of 0.070–0.110 mg/dm^3, at the most remote stations located in the sea - 0.033–0.035 mg/dm^3.

The monitoring in the Contract Area waters carried out in 2006–2016 showed the results that are generally comparable with the data collected in retrospective and current periods. In local areas, the total phosphorus concentrations are higher, but in their entirety the results can be characterized as mesotrophic.

In 2006–2009, long-term average annual median values of mineral phosphorus were: 0.0098 mg/dm^3 - in the Oil field pipeline area; 0.0196 mg/dm^3 - at Kashagan East; 0.0391 mg/dm^3 - at Kalamkas. According to the retrospective data of 1961–1983, in the southern extremity of the eastern part of the North Caspian Sea, during autumn period, the content of mineral phosphorus made up 0.0195 mg/dm^3 [The Caspian Sea, SPb, 1996]. According to long-term observations of the North Caspian Sea, high variability of phosphates was recorded in autumn, with variation coefficients exceeding 100 % and the highest values recorded in the zones of intensive mixing of sea and river water.

In recent years, the content of mineral phosphorus has significantly decreased, according to Roshydromet [E.L. Vinogradova et al, 2011, Yearbook, 2003, 2015–2016] in 2015, it dropped to the average annual level of below 0.010 mg/dm^3 in the Russian sector of the North Caspian Sea shallow-water area.

Hydrocarbons

In the course of environmental monitoring, the concentration of C_{12}–C_{36} fractions total hydrocarbons in samples of sea water was determined, the total concentration of polar and nonpolar hydrocarbons of various genesis (petrogenic, pyrogenic and biogenic) including a wide range of compounds from lower hydrocarbons to oils, greases and fats, dissolved or mixed with water. Hydrocarbons of biogenic origin are always present in water. Especially much biogenic hydrocarbons enter the water during and after massive development of phytoplankton, because the side phytol chain of chlorophyll is the most important source of isoprenoid structures in the biosphere. After "water-blooming", an increased content of biogenic hydrocarbons can lead to imitation of petrogenic pollution. Distribution of hydrocarbon concentrations in seawater in 2006–2016. at all sites is shown in Figure 4.9

In the earlier period of observations (1993–2006), the hydrocarbons concentration ranged from 0.01 to 0.02 mg/dm^3.

According to independent integrated offshore survey carried out in 2010–2016 [Biological Substantiation, 2010–2015, 2016], the range of hydrocarbon concentrations was practically similar to the results of field monitoring (0.008–0.10 mg/dm^3).

Pursuant to the results of monitoring in the Contract Area waters in 2006–2016, the hydrocarbons content was in the range of 0.005–0.10 mg/dm^3.

In 2006–2010, the median concentration of hydrocarbons in Kashagan water area was 0.005 mg/dm^3 (0.1 MPC), in 2011–2016 - 0.018 mg/dm^3 (0.4 MPC). At the beginning of the monitoring, single exceeded MPC levels were recorded: in spring 2006, in spring 2008, in autumn 2008 (the maximum exceeding level was 18.6 MPC). From 2009 to 2016, low concentrations of hydrocarbons were recorded around the EPC islands. High concentrations were recorded in autumn 2013 at most monitoring stations, exceeding the rate level from 2.4 to 15.8 MPC; in 2014: in spring - at stations around artificial islands A, DC01, DC04, DC05; in summer - at monitoring stations located to the east from the islands.

According to Kalamkas monitoring data, the distribution of hydrocarbons is not reliably correlated with the combination of the "year" and "season" factors. The seasonal variations of hydrocarbons are not evident with minimum concentrations observed mainly in autumn seasons (Figure 4.10). The vertical stratification is poor, with predominance of content in the sea bottom layer. Hydrocarbons content of 0.4–0.6 MPC was recorded in spring 2006. Excessive MPC (1.2 MPC) was recorded in spring 2010. Statistically significant changes in concentrations in 2007–2010 were not recorded.

Later, when no operations were performed at Kalamkas field, the results of environmental monitoring showed that high concentrations of hydrocarbons were recorded in spring 2011, in autumn and summer 2013 and in summer 2014. In summer 2014 the largest number of stations recorded excessive MPC (8.6–31.4 MPC), with the maximum value recorded at Kalamkas West in the surface water layer; as well as in autumn 2013 at some stations. In 2006–2016 the coefficient of variation Cv was 2.32 in Kalamkas water basin.

The average content of hydrocarbons along the Oil field pipeline route in the period under study ranged from 0.010 to 0.056 mg/dm^3, the median value being 0.028 mg/dm^3 (0.56 MPC). The average annual content of hydrocarbons in spring is higher than in autumn and summer (concentrations 0.015 and 0.022 mg/dm^3, respectively), except for autumn 2013 when an excess of MPC was recorded at all monitoring stations. A single case of a high concentration of hydrocarbons was recorded in spring 2014 (6.6 MPC).

The median value of hydrocarbon concentrations at Kairan and Aktote fields in 2011–2016 made up 0.030 mg/dm^3 (0.6 MPC). MPC was exceeded in autumn 2013, as well as in spring and summer 2014. Contamination was episodic of a medium level (not higher than 4 MPC). High concentrations of hydrocarbons were recorded at one station in spring and at ten stations in summer 2014.

However, the hydrocarbons content dynamics

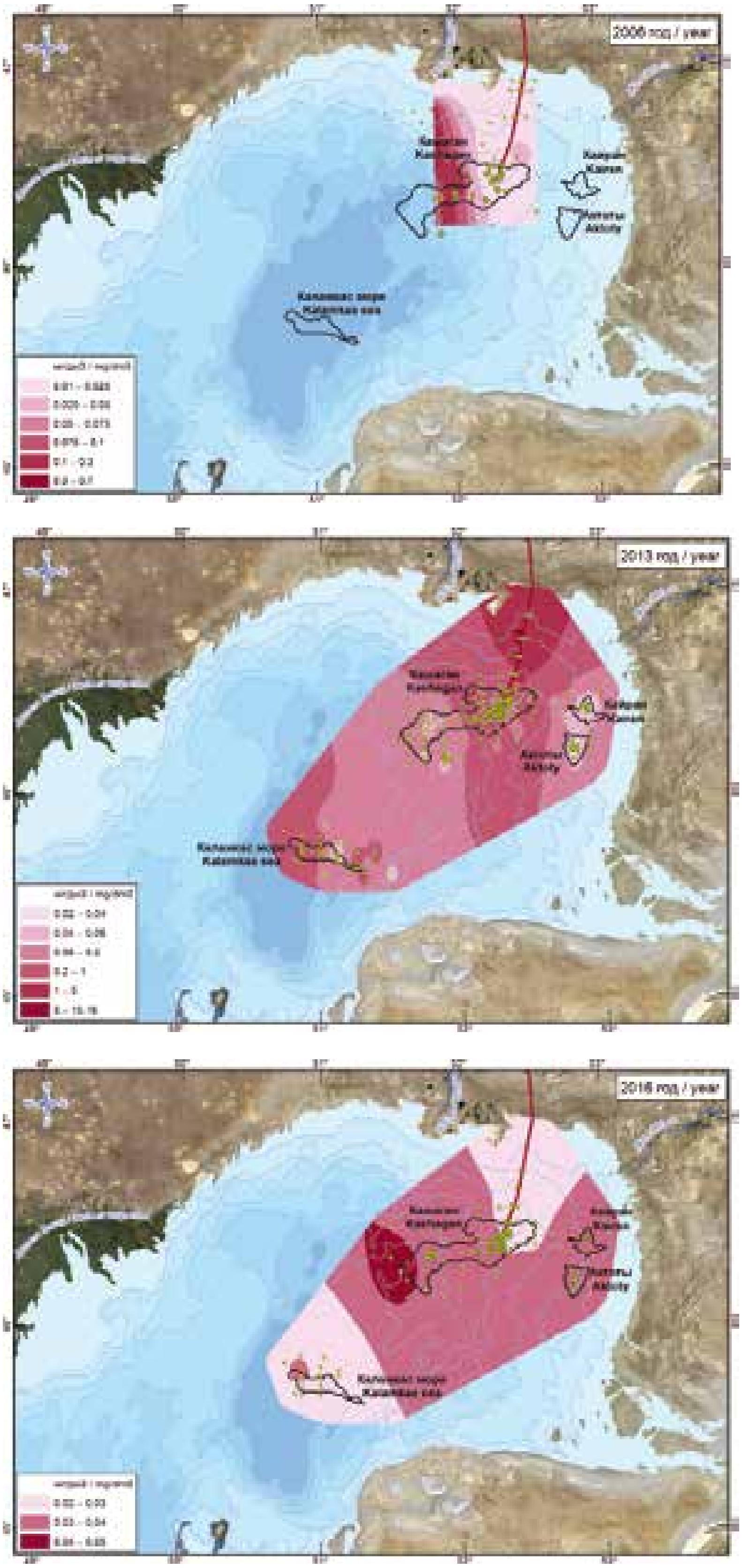


Figure 4.9

Distribution of hydrocarbons in 2006 (spring), 2013 (autumn) and 2016 (autumn) in autumn seasons showed a shift from stable levels of 2011–2012 to their growth in 2013 and decrease later in 2015–2016.

WHEN COMPARING HYDROCARBONS CONCENTRATIONS IN 2006 WITH THOSE RECORDED IN 2016, THERE WAS NO TENDENCY IN GROWTH.

The concentrations did not exceed the MPC level. In all areas under study, the correlation between high hydrocarbon levels and a certain period is not defied or it is weak because the cases of pollution were mostly episodic, local in space and dispersed in time.

The content of hydrocarbons ranged from values significantly below the MPC and up to 32.2 MPC. The excessive concentration was recorded more frequently in 2008 and in 2013–2014, several such cases were recorded in 2015–2016, too. In autumn 2013, in spring and summer 2014, MPC excesses were recorded practically in all water areas under survey. Single high values of concentrations were recorded in Kashagan and Kalamkas areas – 32.2 MPC and 31.4 MPC respectively. The concentration excesses were not so significant (2–3 MPCs) and they can be attributed to the zones of hydrocarbon contamination of the "low" and "middle" levels, both in the surface and in the seabed layers of water. All other higher concentrations were of an unsystematic nature and dispersed in time.

The average annual concentrations in all areas under study were approximately 0.025 mg/dm^3 with the exception of autumn 2013 (0.175 mg/dm^3 - 3.5 MPC), spring and summer 2014 (0.054 mg/dm^3 - 1.1 MPC and 0.188 mg/dm^3 - 3.8 MPC). This is confirmed by independent integrated offshore surveys, according to which the concentrations reached 0.24 mg/dm^3 (4.8 MPC) [Biological Substantiation, 2010–2015, 2016].

Phenols

Phenols are benzene derivatives with one or more hydroxyl groups. Phenols are usually subdivided into two groups - non-volatile phenols and volatile phenols (a group of monohydroxy derivatives of benzene, which includes a number of compounds distilled with water vapor). In toxicological terms, volatile phenols with steam are more toxic. The content of volatile phenols (phenolic index) was determined in sea water (hereinafter - phenols).

Under natural conditions, phenols are formed in the processes of metabolism of aquatic organisms, in the biochemical decay and transformation of organic substances occurring both in the water column and in sea bottom sediments. Phenols are unstable compounds and undergo biochemical and chemical oxidation. The processes of phenol adsorption by sea bottom sediments and suspended mater play a minor role.

Observations of the content of phenols during monitoring are indisputably important due to the variety of their functions. Some phenolic compounds have a detoxifying role fixing toxic substances - heavy metals, pesticides, radioactive elements.

In high concentrations, phenols are toxicants and have a harmful impact on marine life. As a result of chemical and biochemical destruction of phenols, some compounds can be formed, which are even more toxic than phenols themselves.

Observations of seasonal concentrations of phenols make it possible to assess to some extent the trend in the production-destruction process. Thus, phenols are a representative indicator in the hydrochemical and hydrobiological aspects.

The maximum permissible concentration (MPC) of phenols in fishery water bodies is 0.001 mg/dm^3.

In 2006–2016, the range of phenol concentrations was from < 0.0001 to 0.1007 mg/dm^3. The data varies over a wide range of 0.0005–0.06076 mg/dm^3. In autumn 2009 the range of fluctuations was 0.0007–0.06076 mg/dm^3 with the average value of 0.013 mg/dm^3, in spring 2010 - 0.0005–0.0738 mg/dm^3 with the average value of 0.024 mg/dm^3.

Concentrations of phenols above 0.020 mg/dm^3 (above 20 MPC) were recorded at Kalamkas and Kashagan. The concentrations of phenols above 0.0020 mg/dm^3 (above 2 MPCs) were recorded in autumn 2008: at Kalamkas (up to 0.0047 mg/dm^3), at Kashagan (up to 0.0061 mg/dm^3) and in the Oil field pipeline water area (up to 0, 0026 mg/dm^3). Phenol concentrations above 0.010 mg/dm^3 (above 10 MPC) were recorded in autumn 2013

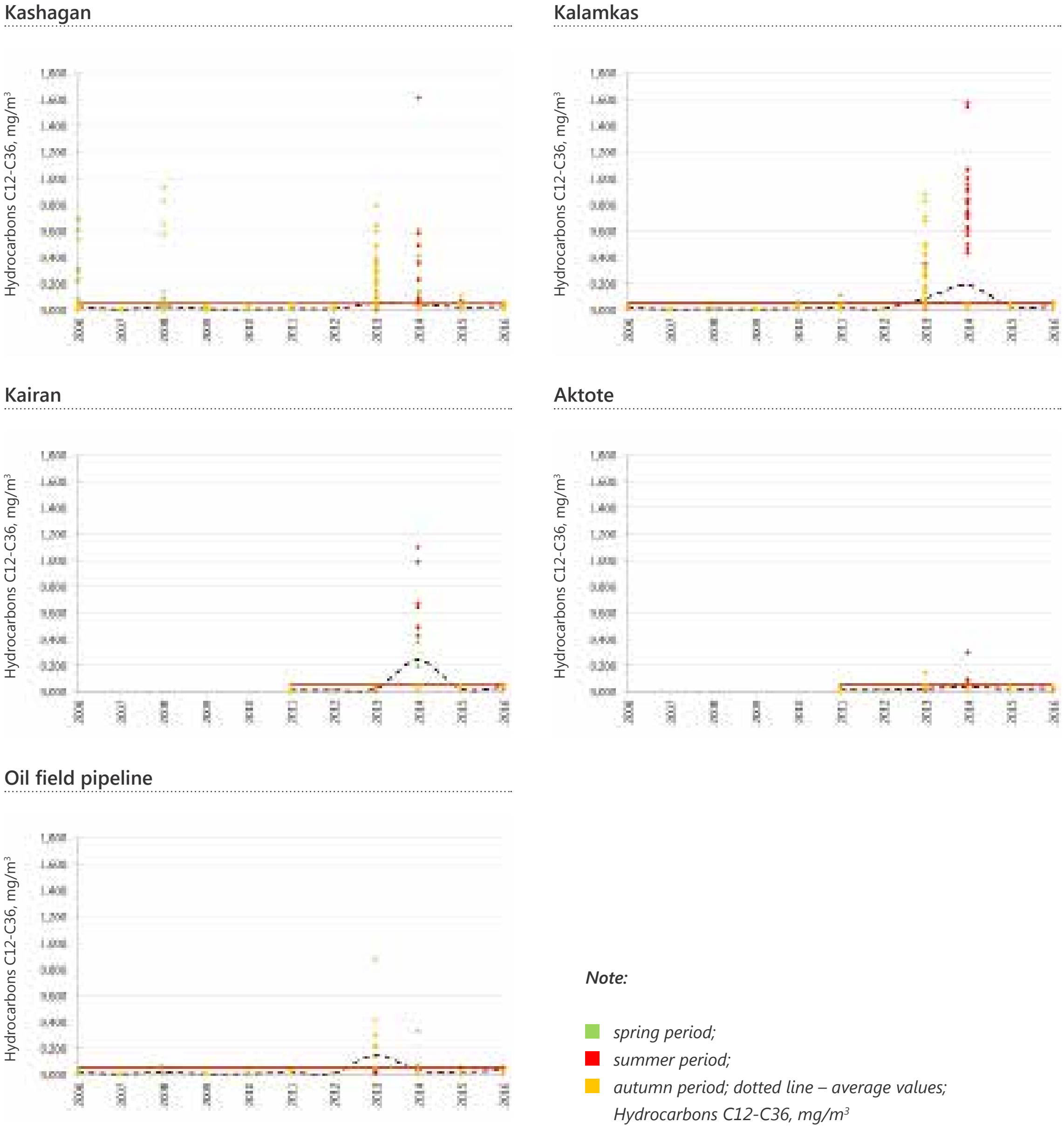


Figure 4.10 Distribution of hydrocarbons in 2006–2016

at Kalamkas (up to 0.013 mg/dm^3) and Kashagan (up to 0.012 mg/dm^3). See Figure 4.11.

In spatial-temporal distribution of phenols, there is no obvious link between higher concentrations and operations sites. However, at the first stage some relation was possible with the areas of trenching operations for pipelines.

In general, the observed differences in seasonal levels of phenol concentrations, the correlation between the seasonal and natural seasonal dynamics (concentrations decreasing from spring to autumn), as well as synchronization of the interannual phenol trend in certain water areas point to the biogenic genesis of phenols. The baseline level of phenols in the North Caspian Sea, according to the references, is not stable.

The average content of phenols in North Caspian Sea reaches 60 mg/dm^3 (60 MPC), and the average value for the waters of this region is 3 mg/dm^3 (3 MPC) [The Caspian Sea, Almaty, 1995]. The average value of phenol content, recorded from 1985 to 1990 ranged from 3.0 mg/dm3 to 9.0 mg/dm^3. The maximum concentrations

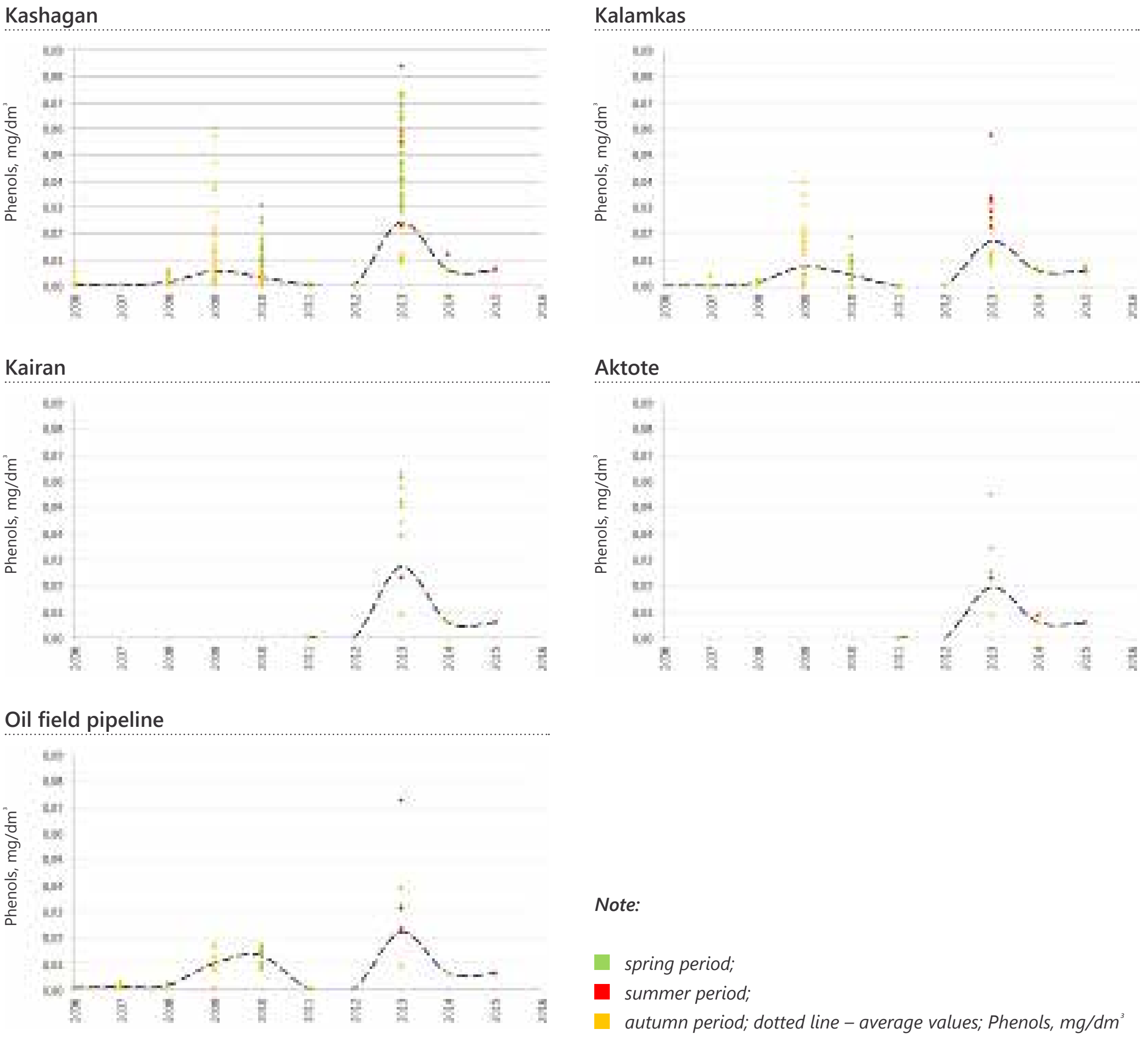


Figure 4.11 Distribution of phenols in 2006–2016

of 30.0 mg/dm³ (30 MPC) were recorded in the marine delta of the Zhayik River (Ural) and in the Ural Furrow [The Caspian Sea, 1994].

Surveys in the North Caspian Sea in autumn 2002 showed that the average content of phenols in the surface water layer was 0.0114 mg/dm³ or 11.4 MPC. In 2015, the average phenol concentration of 1.75 mg/dm³ (1.75 MPC) in the 0–4 mg/dm³ range recorded in the shallow water zone of the North Caspian Sea was slightly higher than in 2014 [Yearbook, 2003, 2015–2016].

The phenols detection rate in samples of sea water in 2011–2016 was one order lower than in 2006–2010.

Heavy metals and arsenic

Throughout 2006–2016, the samples of sea water were analyzed for a multicomponent complex of microelements consisting of 11 metals and arsenic (metalloid). In 2009 (autumn) - 2010 (autumn), aluminum was not found.

1–4 hazard class microelements were analyzed in the samples of sea water.

Cadmium. In 2006–2016, its concentrations were below the limit of analytical detection, and in 100 % of the samples they were below the MPC level, except for the first case when the concentration was 1.55 mg/dm³ (0.2 MPC) at Kashagan in 2011.

Hazard class of microelements	Microelements
Class I, extremely hazardous	Mercury
Class II, highly hazardous	Cadmium
Class III, hazardous	Arsenic, lead, vanadium, chromium, zinc, copper, nickel,
Class IV, moderately hazardous	Barium, aluminum, total iron

At stations of integrated offshore survey, cadmium was found once in 2010 and in 2016 with concentration up to 0.3 MPC [Biological Substantiation, 2010–2015, 2016].

Arsenic was found in the range of 0.73–12.9 mg/dm3 in 3.4 % of samples.

Mercury was found in the range of 0.06–3.6 mg/dm^3 in 1.1 % of samples. At the monitoring site, extensive co-distribution of Hg and As extending from Kalamkas to the coast, was found in 2008 (spring, autumn). During the pollution period (2008), As concentrations were in the range of 0.73–12.9 mg/dm^3 (up to 1.3 MPC). At Kalamkas, which is a deeper water area, arsenic concentrations in the seabed horizon were slightly higher than in the surface horizon. In the same year (2008), the Hg concentrations were in the range 0.06–3.22 mg/dm^3. At Kalamkas, mercury (0.07–0.25 mg/dm^3) was found in the surface and near-seabed layers. At Kashagan, the surface layer only showed mercury contamination with the center of relatively higher Hg concentrations (1.45–3.22 mg/dm^3) at Islands A and EPC3.

During 2006–2016, As and Hg were absent in all other water samples, except for As episodic findings (3.35–4.75 mg/dm^3) and a single Hg finding with concentration of 3.6 mg/dm^3 at Kashagan in 2016. As concentrations were below the maximum permissible concentration in 100 % of the samples.

Concentrations of Hg ≥ 0.5 mg/dm^3 in seawater refer to extreme high contamination level. Sources of As, Hg ingress into water in 2008 are unknown. The simultaneous appearance and disappearance of the pollutants could be provoked both by a single source and by autonomous sources. It can be noted that arsenic and mercury being biocides can be part of biocidal polymers used for anti-fouling and/or anticorrosive coatings (corrosion inhibitors).

Lead in significant amounts was found in the range of 0.16–43.5 mg/dm3 in 6.3 % of samples. The average long-term lead content at Kashagan and Kalamkas is within 0.2–0.3 MPC. At Kairan and Aktote, lead was not found in 100 % of samples.

At Kalamkas, lead was found within the MPC range in all samples in 2007. In 2012, at Kashagan, the zone of relatively high lead concentrations was close to the artificial islands A, D, EPC3.

In the Oil field pipeline water area, the zones where lead was found were located in marginal sections: near the northern border of Kashagan and its higher concentrations (1.6–2.1 MPCs) were found in the landfall area.

According to independent integrated offshore surveys, lead concentrations did not exceed the MPC level [Biological Substantiation, 2010–2015, 2016].

Vanadium is found in the range of 0.1–241 mg/dm3 in 19 % of samples. In 2011–2016, the average long-term concentrations of vanadium significantly decreased compared to 2006–2010 period and are currently recorded in the range of 2–6 mg/dm^3 (2–6 MPC), which, as believed, is largely determined by the natural geochemical baseline.

Extremely high concentrations of vanadium (129–222 mg/dm^3) were recorded in autumn 2008 in the western part of Kalamkas. At Kashagan, high concentrations of vanadium were mainly recorded in 2006 (up to 120 mg/dm^3) and in 2008 (up to 138 mg/dm^3).

Total chromium in the range 0.1–1059 mg/dm^3 was found in 94 % of samples. Average annual concentrations of chromium in 2011–2016 decreased as compared with the concentrations of 2006–2010. Low average annual concentrations of chromium of 3–4 mg/dm3 were recorded at Kairan, Aktote and Kalamkas. In autumn 2008, an abnormally high concentration of chromium equal to 582 mg/dm^3 was once recorded at Kalamkas; in 2016, concentrations of 14–74 mg/dm^3 were recorded at some monitoring stations.

At Kashagan, in spring 2014, abnormally high chromium concentrations (400 mg/dm^3), iron (1672 mg/dm^3) and nickel (138 mg/dm^3) were recorded in one sample, the dynamics can be seen in Figure 4.12.

Zinc in the range 0.35–154 mg/dm^3 was found in 90 % of samples. In 2006–2016, average annual concentration of zinc remained at all sites at rather stable levels up 0.1–0.3 MPC. According to integrated offshore surveys, zinc concentrations were below the MPC level [Biological Substantiation, 2010–2015, 2016].

Copper in the range 0.4–191 mg/dm^3 was found in 88 % of samples. High concentrations of copper (122–173 mg/dm^3) at Kashagan were recorded in 2006. According to independent integrated offshore surveys [Biological Substantiation, 2010–2015, 2016], the average copper content in seawater was in the range of 0.4–7.0 mg/dm^3. The maximum concentrations of this element equal to 33 mg/dm^3 were recorded in 2010, while in other years the values were below the MPC level.

In the period of 2011–2016, at all monitoring sites, the copper concentrations did not exceed 10 mg/dm^3. The copper concentrations distribution can be seen in Figure 4.13. A very different concentration of copper (128 mg/dm^3)

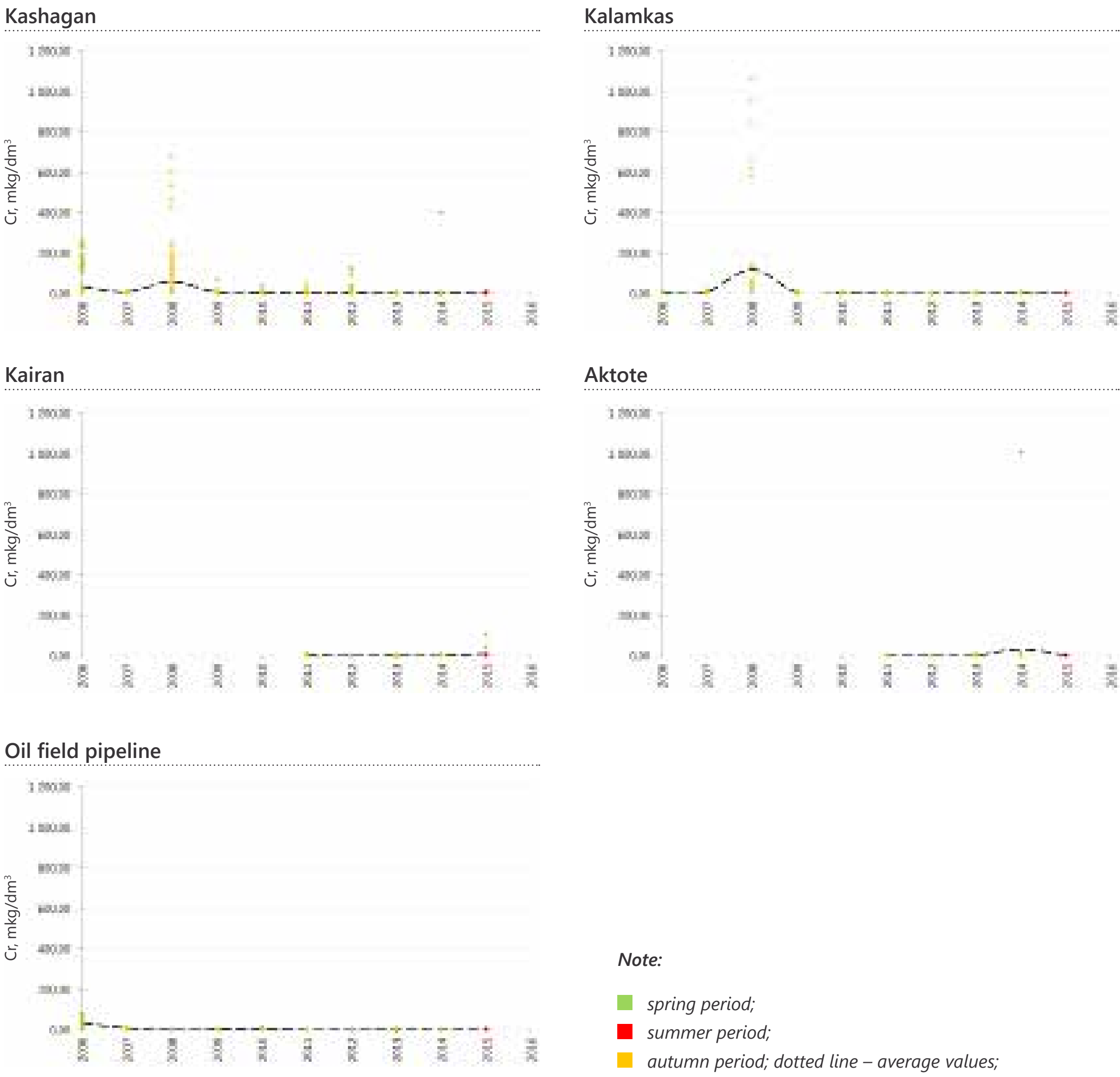


Figure 4.12 Distribution of total chromium in 2006–2016

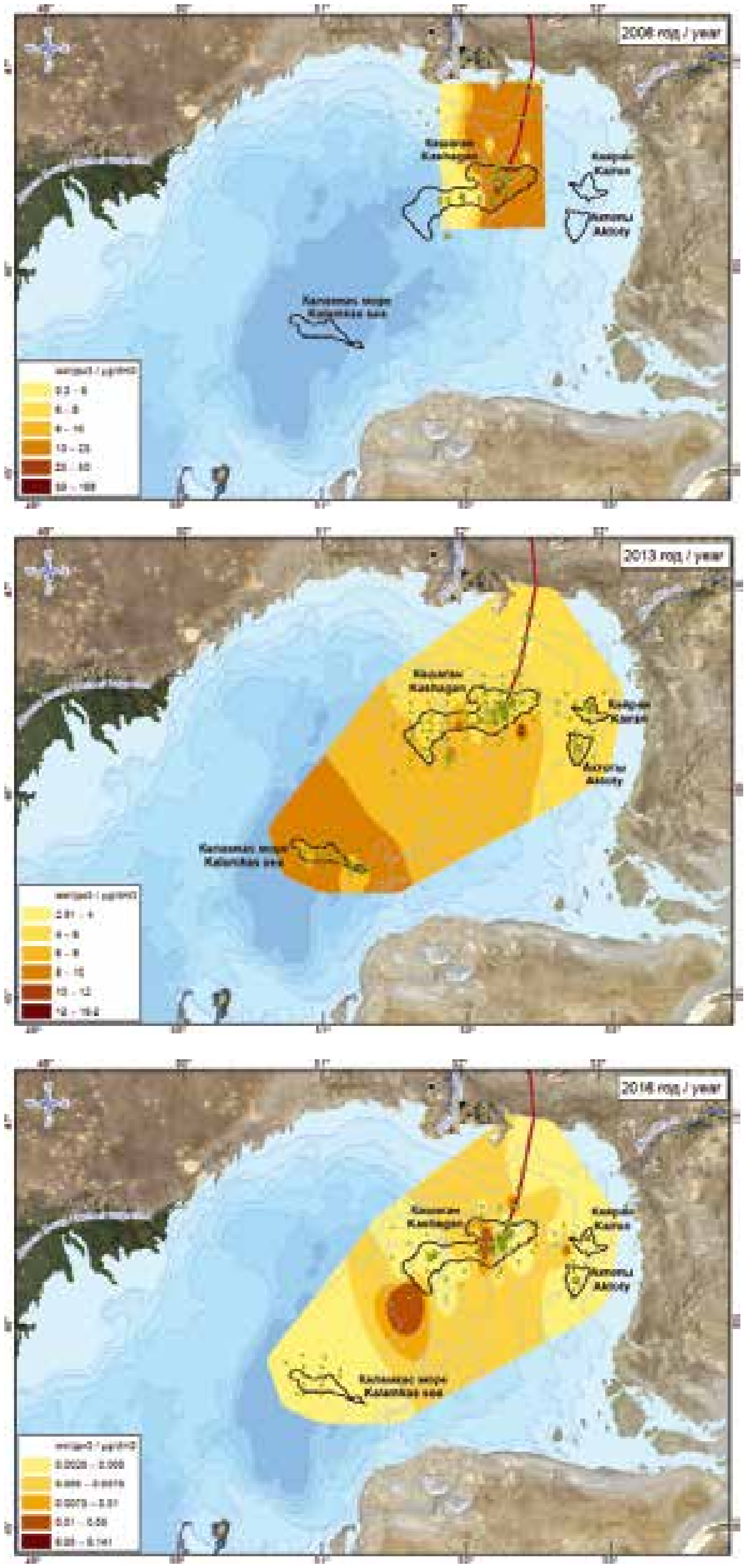


Figure 4.13

Distribution of copper in 2006 (spring), 2013 (summer) and 2016 (summer). Oil fields was recorded once in the Oil field pipeline water area in 2015.

Nickel in the range of 0.15–442 mg/dm^3 was found in 94 % of samples. In 2006–2016, average annual concentrations of nickel remained stable at the level of 0.9–1.1 MPC.

Barium in the range of 1–441 mg/dm^3 was found in 94 % of the samples. The maximum value was recorded in the Oil field pipeline water area in 2016. The average annual dynamics of barium in the monitoring areas is similar to the dynamics of nickel. No excess of MPC was recorded in 100 % of samples.

Aluminum in the range of 0.094 to 4085 mg/dm3 was found in 32 % of samples. Abnormal aluminum levels (1800, 2175 mg/dm^3) were recorded at Kalamkas in autumn 2007 and in 2011 (1334 mg/dm^3). Very high concentrations of aluminum (1100–4085 mg/dm^3) were recorded at Kashagan in 2006.

Total iron in the range of 0.6–3110 mg/dm^3 was found in 11 % of samples. Average annual iron concentration at Kashagan in 2011–2016 decreased by 3 times as compared with the average annual concentration in 2006–2010.

According to published data [The Caspian Sea, 1994], the content of heavy metals in water in the North Caspian Sea was the following: copper - 7 mg/dm3, zinc - 22 mg/dm3, lead - 1.3 mg/dm3 and cadmium - 0.5 mg/dm3.

The current average annual copper concentration (7 mg/dm3) does not differ from the concentration of the end of the last century. Concentrations of zinc (14–18 mg/dm3) and lead (2–4 mg/dm3) are very close to historical data [The Caspian Sea, 1994].

Reduction of negative impacts on the quality of sea water

During all years of monitoring, due consideration was given to determining the content of pollutants in seawater, as they are one of the specific indicators of the impact of operations on the marine environment.

Changes in the quality of sea water in most cases are caused not only by specific operations, i.e. Petroleum Operations in the Company's Contract Areas, but also by a number of other factors of impact (contaminated river inflow, navigation, etc.). However, measures to minimize the impact by every nature user can reduce the overall anthropogenic impact on the seawater. One of the important ways to reduce a negative impact on the seawater is to comply with the requirements of Kazakhstan and international legislation to prevent pollution of the Caspian Sea from vessels. All vessels shall strictly comply with the basic requirements to minimize pollution of the aquatic environment, which will reduce the overall negative impact.

Chemical pollution of sea water and sea bottom sediments during drilling operations is a well-known fact.

THE COMPANY'S DECISION TO TRANSPORT ALL TYPES OF DRILLING WASTE ONSHORE (FOR FURTHER PROCESSING/DISPOSAL) CAN BE CONSIDERED AS ONE OF THE MOST IMPORTANT SOLUTIONS TO REDUCE THE IMPACT.

It is also necessary to note the importance of compliance by the Company with the requirements of Article 262 of the Environmental Code of the Republic of Kazakhstan, which provides general requirements for economic activities in the northern part of the Caspian Sea. In particular, Clause 8 of this Article explicitly prohibits discharge of sewage and waste waters within the State protected area. This measure contributes to the tendency of water pollution decrease in the operational sites of the Company as recorded by monitoring. An important measure can be optimization of the water consumption regime, which will allow reducing the intake of seawater.

In addition to complying with the ban on wastewater discharges into sea, the following basic waste management principles shall be applied to reduce the impact:

- Comply with the ban on the discharge of all types of waste into the water in order to prevent pollution of sea water

- Transport liquid and solid waste in sealed containers only
- Involve only trained personnel in the waste collection and use dedicated vessels for transportation.

However, the most important is development and implementation of measures to prevent and eliminate emergencies. Such measures would allow reducing the impact on the sea water from emergency pollution and they include availability of dedicated vessels, equipment, emergency response plans, staff training, etc. The importance of these measures for emergency prevention has been considered at the governmental level - the National Plan for the Prevention and Response to Oil Spills at Sea and in Inland Water Bodies has been approved (Order No. 134 of the Minister of Energy of the Republic of Kazakhstan, dated 23 February, 2015).

Conclusions

Environmental monitoring in the Company's Areas water basin in 2006–2016 was conducted at sites with different hydrological conditions, however, the average values of the physical-chemical parameters allow establishing the following year-to-year ranges, which fit well into known ideas of the long-term variability of the North Caspian Sea.

The water temperature range is 10.13–27.02 °C. The highest values were recorded in summer in shallow coastal areas, the low values - in the periods preceding the ice cover in the sea.

The average salinity is in the range of 5.64–8.36 ‰. The lower salinity is observed in shallow parts of the Aktote and Kairan fields.

High values of the hydrogen index are mostly recorded at Kashagan field and in the Oil field pipeline area [The Caspian Sea. SPb, 1996]. The measured values reflect the increase in pH level in the North Caspian Sea noted by other modern studies [Vinogradova E.L. et al., 2011, Makaveev P.N., 2009].

At all sites and in all seasons, there are good conditions for the saturation of water with oxygen. The average values are at least 40–50 % higher than 6 mgO2/dm3. The maximum average concentrations of oxygen content reach 16 mgO_2/dm^3 and higher levels in the cold season.

The turbidity value is mainly determined by dynamics of wind and wave, therefore, the average maximum values are recorded at shallow-water stations.

The relationship between turbidity and transparency is inversely proportional. The minimum transparency of 0.1 m is commonly observed in shallow water areas. The maximum values of 4.5–6.2 m were recorded at Kashagan and Kalamkas fields. As compared with turbidity, the transparency is an integral feature of luminance conditions in the water layer. Nevertheless, the correlation coefficient between the turbidity in the surface layer and the transparency reaches -0.83 and at the normal level of about -0.5.

The physical-chemical parameters of the sea water in the North Caspian Sea show a high correlation coefficient (up to 0.99) between the surface and near-bottom layers. In general, we can talk about the value of 0.8–0.9 for temperature, salinity and electrical conductivity, 0.7–0.8 for pH, dissolved oxygen, and turbidity. Temperature and dissolved oxygen (lower temperature at the seabed does not compensate for the lack of exchange with the atmosphere) decrease with depth, while salinity, pH, and turbidity increase. Stable correlation coefficients serve as a kind of control when analyzing the results of measurements. Analysis of the results of monitoring of nutrient elements showed a high interannual, and in some years, an inter-seasonal variability, up to 1–2 orders of magnitude. This is mainly due to a combination of such reasons as the rapid natural dynamics of biogenic compounds. The recorded excessive concentrations of nutrient elements, as a rule, were of a local character, disjointed and short-term. In 2006–2016, biogenic compounds in increased amounts were observed at artificial islands EPC3, EPC2, PLA5 and Oil field pipeline. The levels of biogenic elements observed during environmental monitoring surveys corresponded mostly adequately to the niches of typical indices in the shallow part of the North Caspian Sea, as described in published sources.

Relatively higher levels of biogenic elements were observed in the coastal part, at Kairan and Aktote fields and coastal transects of Oil field pipeline.

The seasonal trend of biogenic compounds is not clearly expressed, there was a predominance of ammonium nitrogen in spring and nitrate nitrogen in autumn, but in general the changeability of the dominant biogenic elements in seasons was observed in different combinations, as well as with significant levels variability..

IN ALL AREAS UNDER SURVEY, THE CORRELATION BETWEEN HIGHER HYDROCARBONS LEVELS AND A CERTAIN PERIOD IS NOT WELL EXPRESSED OR POORLY EXPRESSED,

the pollution was mostly episodic, localized in space and dispersed in time. The content of hydrocarbons at the sites varied from values significantly below the MPC to 6.9 MPC, and the sites can be referred to the zones of hydrocarbon contamination of "low" and "medium" levels in the surface and in the near-bottom water layers. The major excessive concentrations were recorded in 2008, 2013–2014 and in several cases in 2015–2016.

The average annual hydrocarbon concentrations in all areas under survey make up approximately 0.025 mg/dm^3. Except for autumn 2013 (0.175 mg/dm^3 - 3.5 MPC) and spring and summer 2014 (0.054 mg/dm^3 - 1.1 MPC and 0.188 mg/dm^3 - 3.8 MPC).

The observed small scale pollution cannot by unambiguously interpreted as technogenic for the following reasons: the pollution was recorded occasionally in all five areas under review both in surface and bottom layers of water regardless of economic activity; hydrocarbons can also enter the sea water as products of biodegradation and vital activity of organisms. In uncontaminated sea waters, natural baseline concentrations can be up to 2 MPC.

Given the diverse space - time distribution of metals due to heterogeneity of natural geochemical conditions, different technogenic loads and variety of industrial operations, the trends in the levels of their concentrations in the last years of the period under review have shown a reduction. In general, the quality of sea water in the Contract Area waters regarding the content of heavy metals can be considered as satisfactory. The average concentrations of metals, such as cadmium, zinc, barium, iron and arsenic, did not exceed the standard level. With the exception of vanadium and copper, the average annual metal concentrations were within the MPC limits. In the water area under study, the initial (baseline) contamination with copper is typically 1.3 MPC and with vanadium is 2–6 MPC.

Extensive areas of higher concentrations of mercury, arsenic, vanadium and chromium were found in 2008. Single cases of exceeded MPC for lead, total chlorine and aluminum were recorded at Kashagan and Kalamkas fields and for lead in the area of Oil field pipeline, the concentrations in the area of Kairan and Aktote fields did not exceed the standard rates. Average annual concentrations of nickel in the period under study steadily remained at the level of 0.9–1.1 MPC.

5. BOTTOM SEDIMENTS

Analysis of the quality of bottom sediments is regarded as one of components of a general assessment of the condition of the marine environment. Many pollutants do not disseminate in natural waters freely, but tend to attach themselves to various sedimentary particles. These the so-called "carriers" control the spread of pollutants and govern their potential ecological effect. At the same time, bottom sediments can be regarded as a bank of information on the condition of the environment, while the sediments themselves reflect the integrated effect of human impact on the water system.

The properties of bottom sediments, their ability to accumulate and store information on the pollution of the water area allow using them for indication of ecological changes, the condition of a water body or its specific water areas and to control pollution sources. The granulometric composition characterising the degree of dispersion of sediments serves as a reliable indicator of the sedimentation environment and in this manner, their study goes a long way to promoting litho-dynamic and landscape environmental zoning.

Sedimentation in the Caspian Sea bottom is caused by terrigenous (60%), biogenic (30%) and chemogenic (10%) carbonate materials. The terrigenous section is roughly by 65% caused by rivers, while the remainder is caused by wind gain, erosion and coastal abrasion.

The main accumulation is around the central section of the sea, while the northern shallow shelf is, on the whole, an alimentation zone, which is confirmed by absence of a positive sediments transfer balance.

In the north-eastern part of the Caspian Sea, the terrigenous deposits and suspended materials are transferred, mainly, from the Volga and Zhaiyk (Ural) rivers (4.5 million tonnes/year). During the spring, a solid flow from the Zhem (Emba) river and coastal sheet erosion have a secondary effect. The role of wind gain dust particles is viewed differently, with up to 58% of them being of terrigenous origin [Khripunov, Katunin, 2010], while the most intense wind-borne gain occurs during the autumn and spring period [Khripunov, Kovalyev, 1978]. The most common examples of terrigenous bottom sediments are sand, very fine sand, silty sand and clay mud.

THE ACCUMULATION OF POLLUTANTS IN BOTTOM SEDIMENTS DEPENDS SIGNIFICANTLY ON THE DIMENSION OF SEDIMENT PARTICLES, AND, CONSEQUENTLY, ON THE TYPE OF SEDIMENTS.

Smaller sediment particles, such as aleuropelite and pelites tend to have the most sorbent properties. Therefore, the data on the distribution of various lithological types of bottom sediments is important for assessment of various pollutants distribution on the sea bed.

Contemporary bottom sediments in the north-eastern part of the Caspian Sea are mostly represented by carbonate and terrigenous sediments, in which the carbonate portion generally consists of shell remnants of different degrees of preservation, while terrigenous sediments consist of particles of different sizes from sand up to mud. Shells are always present in sandy or mud marine sediments in the form of terrigenous material impurities. Shelly soil is created under certain conditions, especially in the North Caspian region. The ratio of the size of terrigenous particles in bottom sediments determines their character and disposition to pollutant accumulation.

Hydrodynamic activity, distance from the coast and geomorphological parameters all greatly affect the mechanical differentiation of sediments. In 1930–1960, the sediments were composed mainly of sand and shells. However, in 1973, once flow had been controlled, the mud sediment area increased, while in 1980–1990, during the transgression period and taking into account the consequences of changes in the shore slope, the mud and shell sediment area had increased [Khripunov, Katunin, 2010].

5.1 Litho-chemical Conditions

The water body under research can be divided into four zones [Environmental Monitoring .... 2014]:

- Transition zone (up-surge and down-surge zone, Oil field pipeline area)
- Nearshore zone (Aktote and Kairan coastal fields)
- Offshore zone (Kashagan field)
- Deep water zone (Kalamkas site).

The first and second zones are in the active wind and wave impact area. After 2011, due to the drop in the sea level, the active flow dynamics zone began to mix with the offshore section. The composition of sediments in these areas is very similar (Table 5.1-1, Figure 5.1.1 A), and is represented by highly differentiated sediments - predominantly fine sand. A comparison of the granulometric composition of deposits at three sites according to the Mann-Whitney U test showed that sediments composition actually differed only in 4 cases out of 44 pair comparisons at $p<0.05$.

Table 5.1-1 Values of the statistic parameters of the granulometric composition of bottom sediments in the explored water body in 2006–2016 (n is a number of observations, SD is a standard deviation and CV is the coefficient of variation)

		Consistency of the main granulometric fractions, %					
Dimension	**n**	**Average**	**Median**	**Minimum**	**Maximum**	**SD**	**CV**
Aktote							
Pelite	432	9.15	9.02	0.28	67.26	4.65	50.82
Silt	432	4.26	3.37	0.12	30.52	3.91	91.91
Fine-grained sand	432	59.94	60.45	13.96	81.50	7.74	12.92
Moderate and large-grained sand	432	20.37	19.91	1.32	42.35	6.14	30.13
Gravel	432	6.27	6.09	0.02	16.51	2.41	38.39
Kairan							
Pelite	375	11.77	11.38	1.70	62.64	5.13	43.53
Silt	375	5.80	4.80	0.53	43.33	4.77	82.25
Fine-grained sand	375	62.97	65.14	1.07	85.60	10.80	17.15
Moderate and large-grained sand	375	15.29	12.71	1.09	81.30	9.46	61.84
Gravel	375	4.16	3.72	0.00	16.67	2.15	51.58
Oil field pipeline							
Pelite	476	12.97	11.12	0.10	63.70	8.96	69.06
Silt	476	9.01	7.40	0.32	44.20	6.36	70.54
Fine-grained sand	476	63.06	62.84	5.30	93.45	15.67	24.85
Moderate and large-grained sand	476	11.69	5.22	0.00	70.10	13.15	112.45
Gravel	476	3.26	1.25	0.00	23.80	4.06	124.42
Kashagan							
Pelite	4642	8.41	6.75	0.00	65.30	6.95	82.73
Silt	4642	4.96	4.10	0.08	36.30	4.07	82.03
Fine-grained sand	4642	44.41	48.30	0.02	87.60	18.40	41.43
Moderate and large-grained sand	4642	32.53	28.54	0.08	95.51	17.21	52.92
Gravel	4642	9.70	8.93	0.00	58.96	5.20	53.54
Kalamkas							
Pelite	457	13.27	12.60	0.10	44.27	7.85	59.14
Silt	457	7.69	7.30	0.04	35.94	4.89	63.60
Fine-grained sand	457	17.61	16.80	0.10	54.80	11.70	66.45
Moderate and large-grained sand	457	45.26	42.70	10.54	91.88	14.53	32.10
Gravel	457	16.17	14.35	0.58	52.00	7.53	46.58

Sediments in Aktote, Kairan and Oil field pipeline areas did not significantly change in the period from 2006 to 2016. Results show that highly differentiated sediments in mechanical terms, such as fine sand with modal fractions generally exceeding 60%, are more developed in these regions compared to others (Figure 5.1.1 B) [Monitoring reports, 2006–2016]. They are located in shallow water areas (depth of at least 4 m and an average depth of 1.8 m over the 11-month period). It is an active wave impact zone, which explains a high degree of mechanical sediment differentiation. At Aktote field, bottom sediments contain slightly larger fractions (moderate and large-grained sand and gravel), while the fractions are finer along the pipeline route. The smell of hydrogen sulphide was often noted in sediments in this area.

Bottom sediments at all monitoring stations in Kashagan water basin were represented by irregular coarse sand, of which approximately 50% was made up of grain consistency in the range of 0.05–2.0 mm (see Table 5.1.1 and Figure 5.1.1 B). The share of silt (0.05–0.005 mm) and pelite (<0.005 mm) in sediments at the majority of stations did not exceed 30%. The greatest changes in bottom sediments at the site occurred before 2011 (Figure 5.1.1 C). The period after that saw a clear relative increase in moderate and large-grained sand fractions (0.25–2 mm) in sediments due to an evident decrease in the content of smaller granulometric fractions. With completion of active construction activities in the field (2010–2011), which was accompanied by soil damping to build artificial islands, the quantity of fine sand in sediments began to

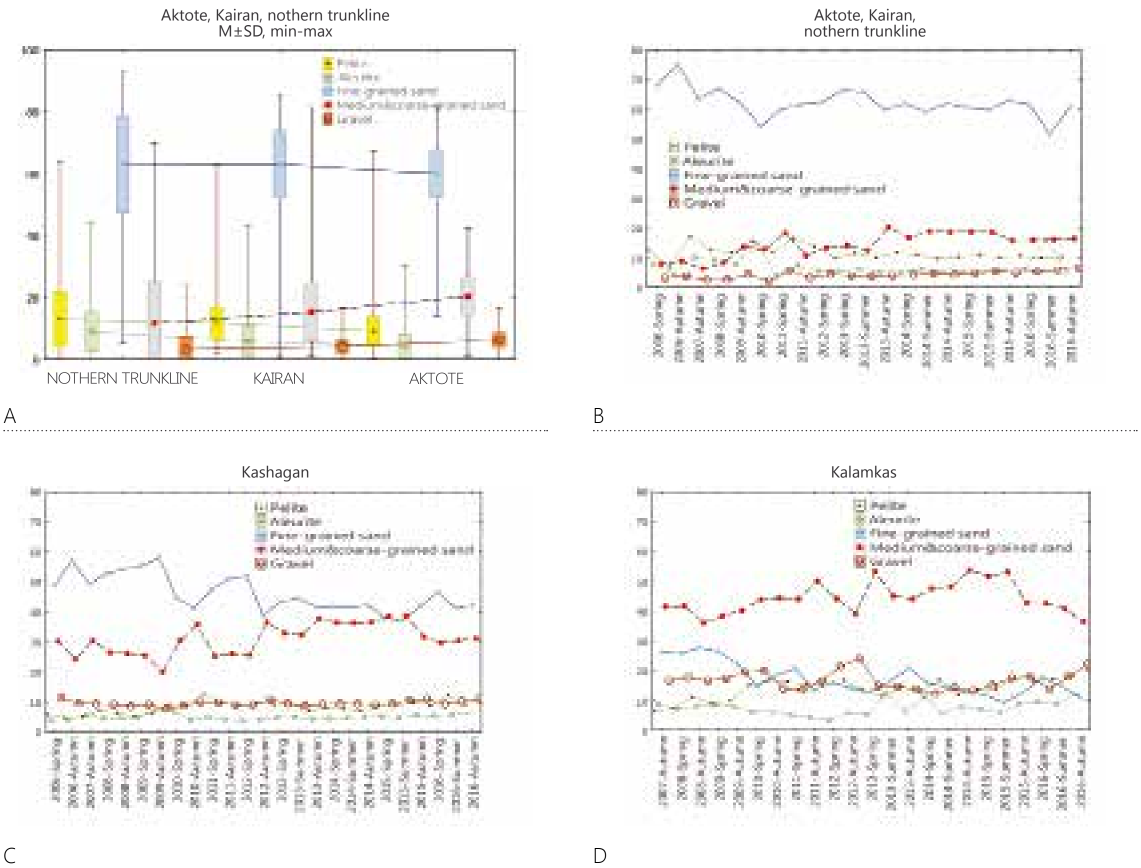


Figure 5.1.1 Comparative analysis of the composition of sediments in Aktote and Kairan water basins and in Oil field pipeline areas (A). Changes in the granulometric composition of sediments in the transition zone and nearshore area (average depth of 1.8 m) (B), offshore section (average depth of 4.2 m) (C) and deep water zone (average depth of 8.4 m) (D) in 2006–2016

decrease considerably. By spring 2013, it had reached values observed in the area before the start of construction activities. Since spring 2013, the granulometric composition of sediments at the artificial islands has stabilised and the content of main fractions remains practically unchanged.

The dominant type of sediments in all survey periods in the deep water zone at Kalamkas field was moderate and large-grained sand. Sediments are less differentiated in granulometric terms, which is confirmed by bimodal curves for the distribution of granulometric composition. Evident biomodality was noted at the Kalamkas field earlier between 1998 and 2000 and then in 2003 and 2004 [Environmental Monitoring...., 2014]. Commercial activity at Kalamkas was suspended in 2009 with the drilling of an appraisal well. Since spring 2009, the shares of moderate and large-grained sand fractions and pelite in sediment have grown. Fine fraction content has always been high and hydrogen sulphide was recorded at Kalamkas site. Coarse material (>2 mm) has never been significant, which is proof of the existence of biogenic sedimentation processes. Major shell detritus formations lead to increase in the quantity of rough material and a drop in mechanical differentiation levels. An increase in the proportion of coarse shell deposits was seen twice in 2012 and 2016. On the whole, the sediment structure changed insignificantly during the observation period, the composition of core granulometric fractions hardly varied. It is probable that the sediment structure was formed under the influence of natural processes of reclassification of sediments and sedimentation, without any man-caused impact.

The oxidation-reduction potential (Eh) and total organic matter content (total organic carbon or TOC) are closely related to granulometric composition. Table 5.1–2 clearly shows that Eh will be lower in bottom sediments with predominant fine fractions. The link between Eh and temperature is similar, which confirms the seasonal migration of Eh across the entire water body of the North-East Caspian Sea. At the majority of sites, minimum Eh values are most often seen during the summer months. Over the "spring-summer-autumn" period, Eh changed as follows: at the sediments depth of 1 cm: +60.3±3.0 mV; -17.3±3.8 mV; +115.8±3.0 mV; at the depth of 4 cm: +2.3±2.8 mV; -73.6±3.5 mV and +41.7±2.5 mV.

In the last 11 years, the value of oxidation-reduction potential of bottom sediments in the North-East Caspian Sea water body has decreased (Figure 5.1.2). In 2006, the average Eh value at the sediment depth of 4 cm was +46.3±7.0 mV (315 measurements). In 2011, Eh = -24.2±6.4 mV (374 measurements).

In 2016, Eh = -65.9±5.5 mV (684 measurements). The same period also saw temporary value increases (for example, 2007 and 2010) and temporary reductions (2011 and 2016). In general, average values characterize sedimens as moderately anaerobic with Eh value between 100 and +100 mV. In 2007 alone, Eh at the depth of 4 cm was above 100 mV (+102.3±10.2). On the surface, average positive Eh values were seen at Kashagan, while at all other sites, except for Kalamkas, slightly negative values dominated.

Table 5.1-2 Spearman's rank-order correlation for the oxidation-reduction potential and bottom sediments parameters in the North-East Caspian Sea in 2006–2016 (Org. C — total organic substance content, highlighted verified values for $p<0.05$)

Index	Eh, 1 cm, mV	Eh, 4 cm, mV	Org. C, mg/kg
Eh,1 cm, mV	1.00	**0.87**	**-0.27**
Eh,4 cm, mV	**0.87**	1.00	**-0.30**
Org. C, mg/kg	**-0.27**	**-0.30**	1.00
Pelite %	**-0.43**	**-0.45**	**0.43**
Silt, %	**-0.34**	**-0.37**	**0.32**
Fine-grained sand, %	**-0.12**	**-0.07**	**-0.24**
Moderate and large-grained sand, %	**0.28**	**0.25**	**-0.04**
Gravel, %	**0.29**	**0.20**	0.02
T°C, 1 cm	**-0.30**	**-0.31**	0.01
T°C, 4 cm	**-0.30**	**-0.30**	**-0.10**

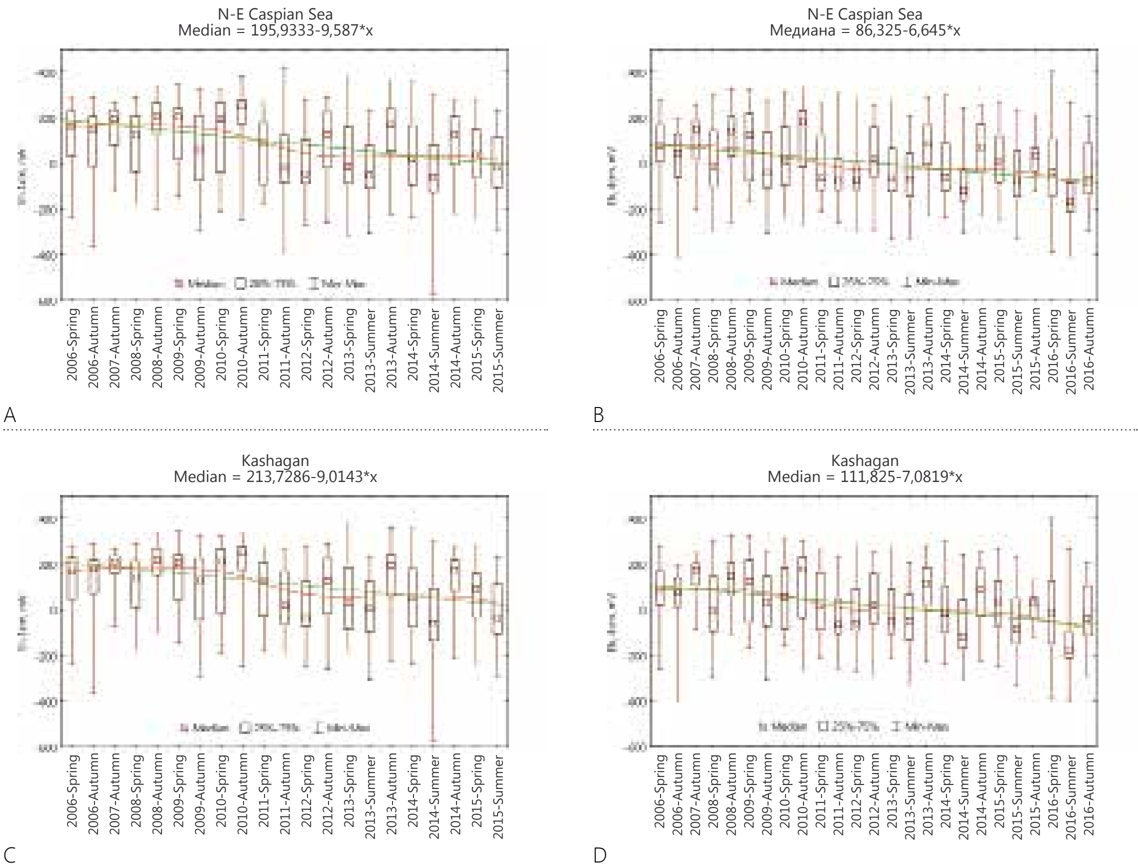


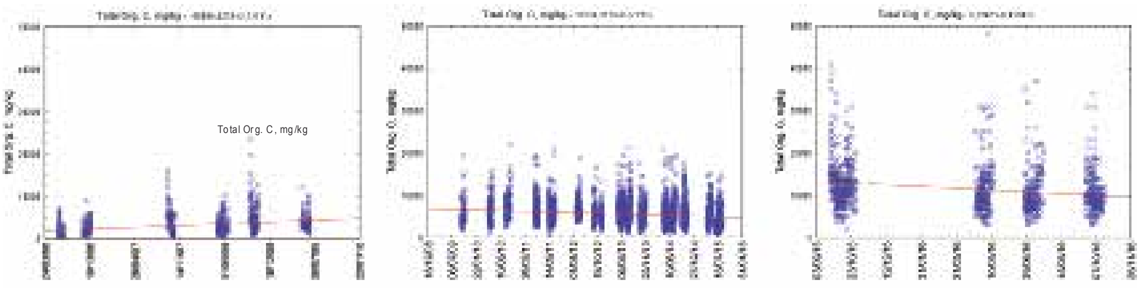
Figure 5.1.2 Year-to-year changes in median Eh values (mV) at sediments depth of 1 cm (A and C) and 4 cm (C and D) for the entire water basin (surface) and for the Kashagan field water basin (below)

Changes in Eh at Kashagan defined a general picture of the parameter change in the North Caspian Sea water basin (Figure 5.1.2). This was primarily due to the fact that out of 11,395 measurements, 8,372 were taken at Kashagan. Sediments at Kashagan field turned out to be more oxidised than in other water bodies. At other water bodies under survey, the year-to-year changes were either insignificant or demonstrated Eh increase trends (nearshore sites).

It is quite likely that under North-East Caspian Sea conditions, the Eh value is determined by the quantity of easily oxidised organic substances in bottom sediments. In this respect, it is worth noting that a storm or human-caused turbidity of bottom sediments provides a local additional inflow of oxygen in the reaction zone, irrespective of all other physical and chemical factors.

Organic matter content is not a standardised benchmark. For the North Caspian Sea, it is normally less than 10,000 mg/kg, and rarely higher than 20,000 mg/kg [Caspian Sea, 1989]. In the North Caspian Sea adjacent water area, under similar conditions at the LUKOIL field, the organic substance content in sediments ranges between 1,000 and 5,000 mg/kg [Review of Findings, Astrakhan, 2016(a); 2016 (b), 2016 (c)]. According to outcomes of survey in the North-East Caspian Sea in 1996–2006 [Environmental Monitoring..., 2014] TOC generally varies between 1,000 and 35,000 mg/kg, depending on the nature of the soil and distance from the coast. In autumn 2001, according to the Caspian Ecological Programme, TOC in Kashagan field sediments averaged 3,600±490 mg/kg. In autumn 2000, TOC in sediments for the entire North-East Caspian water body was 5,000±1,110 mg/kg (according to: [I Tolosa, S Mora, 2004], excluding deep-water and pre-Ural stations).

Total organic substance content in the above survey consisting of 7,044 measurements



A B C

Figure 5.1.3 Changes in total organic substance content in the bottom sediments of the North-East Caspian Sea in 2006–2016 for the three survey periods (explanations in the text)

averaged 6,129.1±47.99 mg/kg (minimum of 24.3; maximum of 48,000 mg/kg). Over 11 years of observations, analytical laboratories engaged to measure organic substances changed three times. The analytical methods (and results) differed slightly in each of the laboratories, which somehow hindered the analysis of the total data set. Splitting of findings into three subsamples (Figure 5.1.3) based on different laboratories they came from, confirmed absence of any considerable trend in each subsample, although it is quite possible that organic substance content in sediments increased in the period of 2006–2008. The highest TOC was seen in the deep water zone (Kalamkas), averaging 9,379.0±250.5 mg/kg. According to a survey taken as part of the Caspian Ecological Programme, the lowest value was seen at Kashagan (5,747.5±54.2 mg/kg), which is 61% higher than in 2001 [Environmental Monitoring..., 2014].

5.2 Quality of Bottom Sediments

5.2.1 Metals and Arsenic

A wide range of bottom sediments characteristics has been analysed, however, it is still difficult to assess any deviations from the norm. No benchmarks exist for bottom sediment pollution levels such as MPC. This is due to the difficulty in standardizing an extremely diverse environment, both from natural physical and chemical characteristics, and mechanical characteristics. A number of scales for assessing bottom sediments is established abroad. They can be applied to the Caspian Sea basin very hypothetically because this isolated inland water body differs from both purely marine and fresh water bodies. In this study, we have applied criteria of eco-toxicological assessment of bottom sediments quality as proposed in the Oslo-Paris Agreement (OSPAR) [OSPAR 2004.] (Table 5.2-1). These assessment criteria do not have legal significance and may only be used for a preliminary assessment of monitoring data to identify potential problematic water areas.

THE MAIN GROUP OF Al, Fe, Zn, Cr, Pb, Cu AND V METALS DEMONSTRATES STABLE COMPOSITION DYNAMICS IN BOTTOM SEDIMENTS, WHILE SOMETIMES (Cu AND Zn) SHOWS DECREASE OF CONCENTRATION (Figure 5.2.1).

Aluminium, barium and iron are always present in significant quantities (Table 5.2-1). Aluminium and iron are the most significant metals from the terrigenous group, which includes Al, Fe, V, Zn, Co, Ni, Cr, Pb, Cu, Cd and As. The majority of metals in this group are closely linked to aluminium and fine bottom sediments fractions. The origin of barium is likely to be related to use of its salts in drilling muds.

It needs to be clear that metals and arsenic, as opposed to organic compounds, cannot disappear completely, but can only redistribute themselves. Presumably, metals and their binding clay minerals can remain in the Ural Furrow.

By assessing the entire period under study, it can be stated that metal and arsenic concentrations are subject to regular fluctuations, but very rarely

Table 5.2-1 Concentrations of metals and arsenic (mg/kg) in bottom sediments from various water areas of the North-East Caspian Sea and their compliance with OSPAR standards (m — error of mean)

Element	n	Mean. ±m	Median	Min.	Max.	Upper OSPAR ecotoxicological standard* Standard	Percentage deviation from the standard ±m	Maximum percentage value
North-East Caspian Sea								
Al	6461	2,720.5±27.7	2.279	8.09	52,300	n/a	n/a	n/a
As	6985	2.42±0.03	1.80	0.05	23.10	10	0.24±0.0028	2.31
Ba	6987	62.74±0.31	60.60	0.03	881.10	n/a	n/a	n/a
Cd	6986	0.20± 0.001	0.20	0.01	1.65	1	0.20±0.0011	1.65
Cr	6985	6.74±0.08	5.28	0.10	67.00	100	0.07±0.0008	0.67
Cu	6986	3.82±0.03	3.19	0.05	60.00	50	0.08±0.0007	1.20
Fe	6985	2,778.0±22.1	2313	9.31	25231	n/a	n/a	n/a
Hg	6986	0.10±0.0001	0.10	0.10	0.30	0.5	0.20±0.0001	0.59
Ni	6987	12.74±0.11	11.50	0.17	112.00	50	0.25±0.0022	2.24
Pb	6986	2.54±0.02	2.29	0.03	21.27	50	0.05±0.0003	0.43
V	6985	9.62±0.07	8.34	0.20	62.70	n/a	n/a	n/a
Zn	6984	8.50±0.07	7.12	0.10	87.00	500	0.02±0.0001	0.17
Kashagan								
Al	4643	2,302.2±26.1	2,000	8.09	35,056	n/a	n/a	n/a
As	5052	2.38±0.04	1.63	0.05	22.70	10	0.238±0.004	2.27
Ba	5053	61.69±0.32	59.70	0.03	809.00	n/a	n/a	n/a
Cd	5052	0.20±0.00	0.20	0.01	1.65	1	0.200±0.001	1.65
Cr	5051	5.71±0.09	4.60	0.10	61.50	100	0.057±0.001	0.61
Cu	5052	3.46±0.04	2.93	0.05	43.60	50	0.069±0.001	0.87
Fe	5052	2,368.1±18.2	2,090	12	25,231	n/a	n/a	n/a
Hg	5053	0.10±0.0001	0.10	0.10	0.30	0.5	0.2±0.0001	0.59
Ni	5053	11.93±0.12	11.10	0.17	100.00	50	0.239±0.002	2.00
Pb	5053	2.36±0.02	2.16	0.03	21.27	50	0.047±0.000	0.43
V	5051	8.53±0.06	7.74	0.20	58.60	n/a	n/a	n/a
Zn	5052	7.44±0.07	6.50	0.10	87.00	500	0.015±0.000	0.17
Oil Field Pipeline								
Al	460	5,361.4±202.3	4,400.5	636	52,300	n/a	n/a	n/a
As	519	2.84±0.07	2.76	0.30	12.90	10	0.284±0.007	1.29
Ba	519	54.71±0.94	52.00	18.90	266.00	n/a	n/a	n/a
Cd	519	0.20±0.00	0.20	0.02	1.43	1	0.204±0.005	1.43
Cr	519	14.49±0.52	11.90	0.10	67.00	100	0.145±0.005	0.67
Cu	519	6.20±0.19	5.51	0.75	60.00	50	0.124±0.004	1.20
Fe	518	5,536.2±155.8	4,884	9.31	24,320	n/a	n/a	n/a
Hg	519	0.10±0.0001	0.10	0.10	0.14	0.5	0.20±0.0002	0.28
Ni	519	16.40±0.40	15.00	0.20	63.00	50	0.328±0.008	1.26
Pb	519	3.68±0.08	3.35	0.14	11.50	50	0.074±0.002	0.23
V	519	16.64±0.44	14.40	3.30	62.70	n/a	n/a	n/a
Zn	517	15.65±0.40	14.20	1.00	61.60	500	0.031±0.001	0.12

Element	n	Mean. ±m	Median	Min.	Max.	Upper OSPAR ecotoxicological standard*		
						Standard	Percentage deviation from the standard ±m	Maximum percentage value
Kalamkas								
Al	449	2,800.5±79.7	2,729	162	12,931	n/a	n/a	n/a
As	505	2.54±0.11	2.14	0.30	23.10	10	0.254±0.011	2.31
Ba	506	63.28±0.74	62.50	5.10	174.00	n/a	n/a	n/a
Cd	506	0.20±0.00	0.20	0.03	0.85	1	0.202±0.005	0.85
Cr	506	5.91±0.18	6.00	0.10	31.70	100	0.059±0.002	0.32
Cu	506	4.43±0.09	4.20	0.52	13.50	50	0.089±0.002	0.27
Fe	506	2,750.6±55.3	2,595.5	300	9418	n/a	n/a	n/a
Hg	506	0.10±0.0002	0.10	0.10	0.20	0.5	0.20±0.0004	0.40
Ni	506	19.28±0.79	15.60	0.69	112.00	50	0.386±0.016	2.24
Pb	506	2.51±0.06	2.42	0.05	11.40	50	0.050±0.001	0.23
V	506	9.24±0.21	8.62	1.00	51.40	n/a	n/a	n/a
Zn	506	8.25±0.26	7.53	0.10	83.80	500	0.016±0.001	0.17
Aktote								
Al	484	2,859.7±70.2	2,725.5	464	17,788	n/a	n/a	n/a
As	484	2.07±0.05	1.88	0.30	8.90	10	0.207±0.005	0.89
Ba	484	74.87±1.94	73.30	32.80	881.10	n/a	n/a	n/a
Cd	484	0.21±0.00	0.20	0.05	0.70	1	0.207±0.003	0.70
Cr	484	7.06±0.17	6.62	1.00	41.70	100	0.071±0.002	0.42
Cu	484	3.58±0.07	3.32	0.82	15.90	50	0.072±0.001	0.32
Fe	484	2,919.7±69.1	2,710	202	16,298	n/a	n/a	n/a
Hg	483	0.10±0.00	0.10	0.10	0.18	0.5	0.20±0.0003	0.35
Ni	484	10.24±0.21	10.40	1.34	46.50	50	0.205±0.004	0.93
Pb	483	2.68±0.05	2.56	0.51	9.51	50	0.054±0.001	0.19
V	484	10.04±0.22	9.52	1.90	57.40	n/a	n/a	n/a
Zn	484	8.47±0.19	7.81	1.63	43.90	500	0.017±0.000	0.09
Kairan								
Al	425	4,187.8±86.6	3,919	207	17,101	n/a	n/a	n/a
As	425	2.68±0.05	2.65	0.30	8.49	10	0.268±0.005	0.85
Ba	425	70.59±1.96	67.60	24.90	617.00	n/a	n/a	n/a
Cd	425	0.21±0.00	0.20	0.05	0.78	1	0.210±0.003	0.78
Cr	425	10.21±0.21	9.79	2.10	47.30	100	0.102±0.002	0.47
Cu	425	4.75±0.10	4.46	1.04	26.10	50	0.095±0.002	0.52
Fe	425	4,160.6±85.3	4,042	23	19,322	n/a	n/a	n/a
Hg	425	0.10±0.0003	0.10	0.10	0.20	0.5	0.20±0.0006	0.4
Ni	425	12.99±0.24	13.10	2.32	50.50	50	0.260±0.005	1.01
Pb	425	3.24±0.06	3.23	0.32	11.20	50	0.065±0.001	0.22
V	425	14.07±0.26	13.70	3.30	52.70	n/a	n/a	n/a
Zn	425	12.77±0.28	11.90	3.50	47.60	500	0.026±0.001	0.10

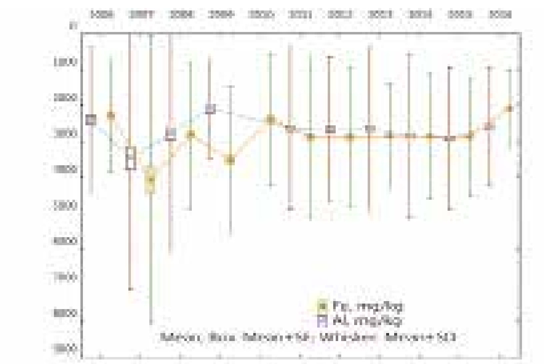
Note: ** – Oslo-Paris Agreement 2004 [OSPAR 2004]* exceed international OSPAR standards and only in some samples. OSPAR standards are exceeded for cadmium in 0.14% of all samples, for arsenic in 2.36% of all samples and for nickel in 1.22%. Without doubt, arsenic and nickel have high natural background levels in the region.

Almost all cases of nickel excesses were found in 2007–2008 (Figure 5.2.1), predominantly at Kashagan and Kalamkas. Only four cases were identified later in the areas of Oil field pipeline, Kairan and Kashagan fields.

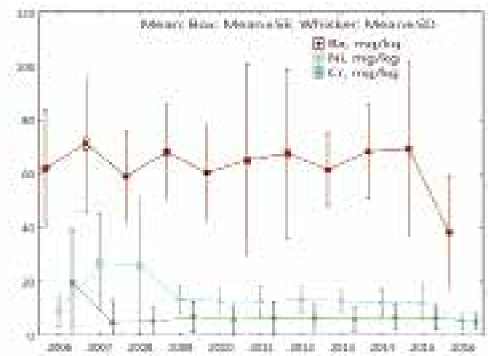
The vast majority of cadmium measurements showed a concentration lower than the detection level. Significant quantities were not identified every year. Ten measurements showed concentrations in excess of 1 mg/kg. Nine out of 10 cases of excess cadmium results were identified in 2016, which we explain by change of an analytical laboratory and the methods used. Mercury is present in concentrations lower than the detection level, with significant concentrations identified only after 2015.

Arsenic dynamics in bottom sediments causes some concern. For example, in spring 2009, arsenic concentration increased and stabilised at its new level. Sometimes (165 times out of 6,985 measurements), concentrations exceeded the critical level of 10 mg/kg (Figure 5.2.1). This increase, as turned out, was caused by a change in the sampling and analysis methods used by one laboratory, and cannot be interpreted as real changes.

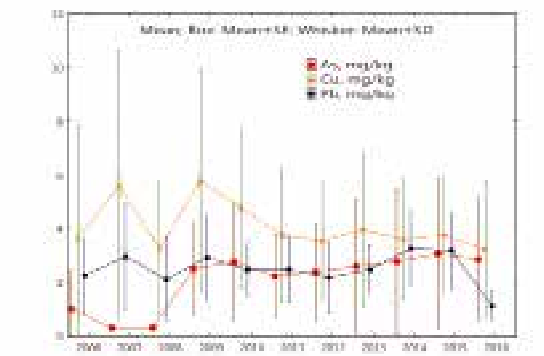
There is no evident relation between the operations and metal content in bottom sediments. Even barium, with its salts used for drilling mud, does not show any relation with drilling operations in the water basin (Figure 5.2.2 A). At Aktote and Kairan fields, where barium content is the highest, drilling was carried out till 2006. At Kashagan, where drilling operations



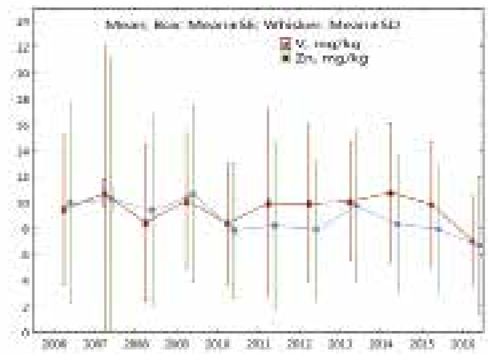
Aluminium and iron



Barium, nickel and chrome

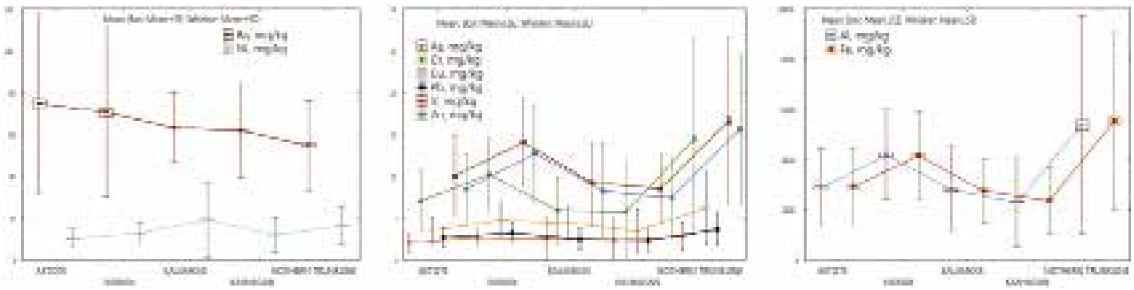


Arsenic, copper and lead



Vanadium and zinc

Figure 5.2.1 Year-to-year changes in metal and arsenic content in North-East Caspian Sea bottom sediments

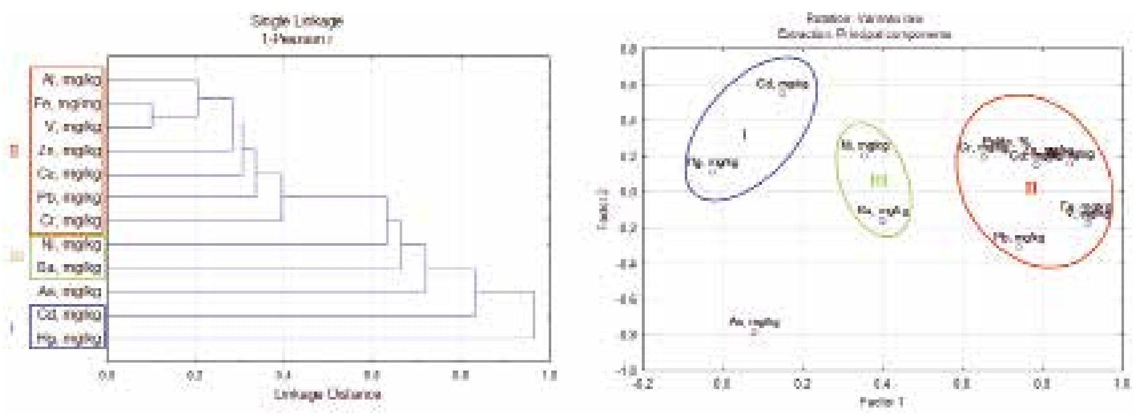


A B C

Figure 5.2.2 Metal concentration in bottom sediments in different sites of the water basin in 2006–2016

were performed permanently, the average barium content was even lower than the average value for the entire area (Table 5.2-1). Only nickel has demonstrated a bent to a deeper section of Kalamkas field (Figure 5.2.2 A). Copper, arsenic and lead are sufficiently evenly distributed across the water body (Figure 5.2.2 B). All other metals (Al, Fe, V, Cr and Zn) have demonstrated (Figures 5.2.2 B and C) an evident dependence of their concentration in sediments on the distance from the coast. The Oil field pipeline route and Kairan field are located in the coastal vegetation belt, which is in the nearshore zone. Proximity to the coast explains the increased terrigenous metal content in these areas.

A cluster analysis and factor analysis (Figure 5.2.3) have visually demonstrated the split of metals into three groups or clusters. The first group includes metals present in trace quantities. The second group includes terrigenous metals, which are closely associated with pelite and silt sediment. The third group (Ba and Ni) is slightly linked to fine sediment (correlation at 0.1–0.2 and 0.2–0.3 levels, respectively). The source of these metals is not likely local or natural. The source of barium, is possibly barium drilling mud used at onshore facilities (terrigenous inflow and eolian entry). The spatial distribution of barium across the water basin is relatively uniform (Figure 5.2.4), and is not linked to offshore drilling operations, which indirectly confirms its terrigenous origin. Ni content in sediments clearly reflects high natural baseline levels. Furthermore, a specific feature of Karazhanbas oil (oil from the Karazhanbas, Buzachi North and Kalamkas onshore fields) produced at the Bozaschi Peninsula is its vanadium and nickel content. An additional source of nickel is probably the Zhaiyk (Ural) River inflow. Stephen de Mora and co-authors [De Mora, 2004] discovered a localised maximum concentration (54.8 mg/kg) in the Zhaiyk (Ural) river estuary, which explains well



Pearson "nearest neighbour" clusterisation method

Analysis of principal components with orthogonal rotation

Figure 5.2.3 Tree diagram and component diagram of element association in bottom sediments in the North-East Caspian Sea

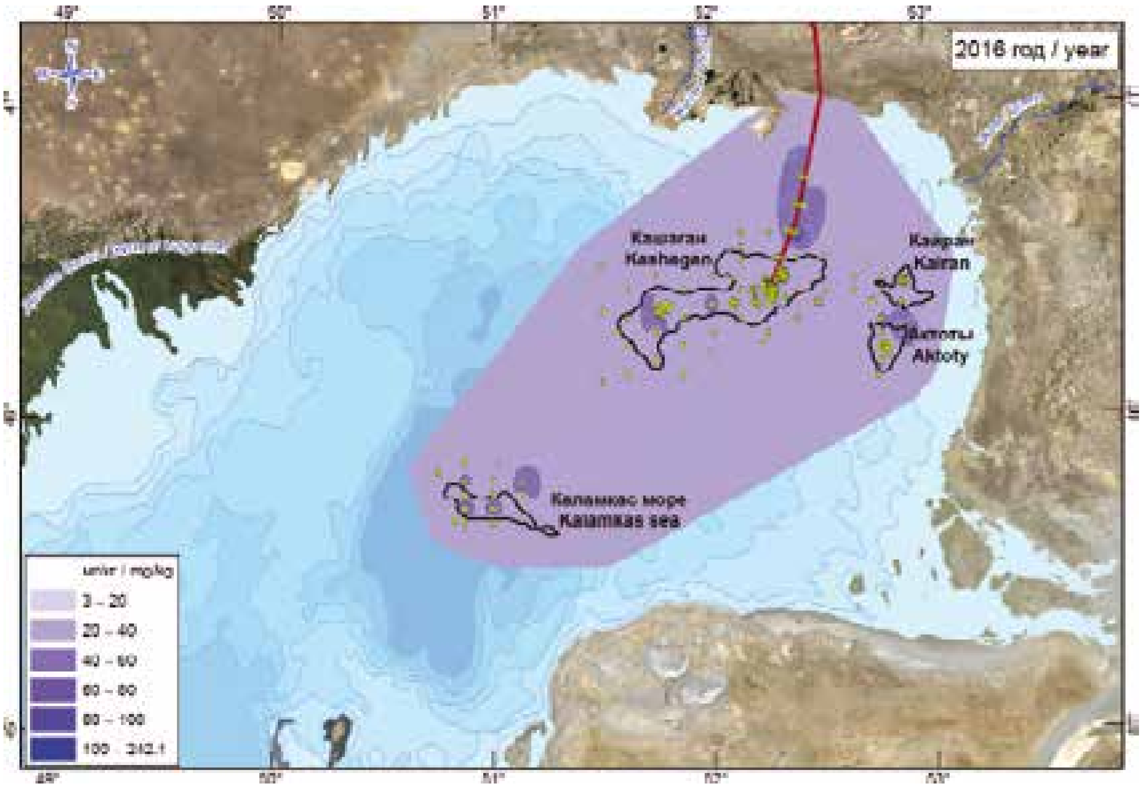


Figure 5.2.4 Barium distribution in spring 2016

the increased nickel concentration at Kalamkas field (Figure 5.2.2 A).

Cattell "scree" criteria for factor analysis clearly indicate the existence of only two main factors determining the concentration value of metals and semi-metals in North-East Caspian Sea bottom sediments. A component analysis of the distribution of metals and arsenic showed that 51.4% of the dispersion is explained by factor 1, which may easily be identified as containing fine sediment fractions. Factor 2 is responsible for 11.8% of dispersion, and is significant for cadmium and arsenic content. It is possible that factor 2 is linked to the change in analytical laboratories or analysis methods.

Arsenic has completely different recordings and shows a very minor correlation with other bottom sediment readings. Maximum Spearman rank-order correlations tie in arsenic with vanadium (0.42), iron (0.40) and total organic substance (0.31) content. At greater depths, the correlation is negative (-0.22).

A comparison of metal and arsenic concentrations in monitoring of sediments in period one and two (2006–2010 and 2011–2016) with reference data [Review of Findings, Astrakhan, 2016 a), (b), and (c); De Mora, 2004] showed that only average nickel concentrations in both periods exceeded the results of year 2000 and were at the concentration levels identified by LUKOIL (Table 5.2-2). The highest values in this study exceeded the maximum values according to De Mora, et al., 2004 [De Mora, 2004]. It is possible that the maximum values for a number of metals were exceeded due to the significantly high research sampling in 2006–2016. The results received by LUKOIL at V. Filanskii and Y. Korchagin fields were approximately similar to the levels of the North-East Caspian Sea. The comparison of 1996–2006 monitoring data and contemporary data is illustrative [Environmental Monitoring, 2014] (Table 5.2-2). The 1996–2006 concentrations were averaged for three water bodies: Kashagan and Kalamkas fields and Oil field pipeline route. Historically, only nickel concentration in bottom sediments has increased, which is probably caused by the onshore production of Karazhanbas oil enriched with nickel and vanadium. The study conducted as part of the Caspian Ecological Programme in autumn 2001 shows that the content of nearly all metals in 2001 at Kashagan was higher than contemporary levels. The exception is nickel whose concentration in sediments in 2001 was lower (9.84±1.41 mg/kg compared to 11.93±0.12 mg/kg today; taking into account average errors — the values were nearly equal). It is possible that this is due to impact of onshore oil production [Environmental Monitoring, 2014].

A comparison with the fundamentally different South Caspian Sea [Khrustalyev, 1978; H R Pakzad, M Pasandi, 2016] showed that in the North Caspian Sea the average metal and arsenic concentration in sediments was 2–8.8 times lower, and 40 times lower for copper.

5.2.2 Hydrocarbons and phenols

Phenol content in bottom sediments across the entire North-East Caspian Sea is assessed in the range from theoretical zero to 3.23 mg/kg (Table 5.2-3), which does not exceed the level noted for the entire North Caspian Sea. Maximum phenol concentrations of 3.2 and 3.23 mg/kg were discovered at Kashagan field in summer 2013 and spring 2014, respectively. At all other sites, phenol content was lower than 2 mg/kg. The difference in phenol concentration across the sites is extremely small (Figures 5.2.5 A and 5.2.6).

A dispersion analysis showed that only 1.4% of total dispersion is explained by the field sample collection factor, which may be because the North-East Caspian water body has natural and indigenous phenols not related to man-caused sources and onshore activities. The situation is confirmed indirectly by seasonal changes in phenol concentration (Figure 5.2.5 B). In summer, a large quantity of vegetable and animal organic materials enter from the water column. The products of the incomplete mineralisation of organic substances, including phenols, accumulate in sediments due to lack of oxygen.

Prior to commencement of large-scale operations, the average phenol concentration in 1996–2006 at Kashagan and Kalamkas fields was 0.39 mg/kg, with maximum concentration of 4.6 mg/kg. Over the last decade, phenol content has not increased. To understand the phenol content in bottom sediments, the so-called "Dutch rates" [Verbruggen, 2000] can be applied. These rates define the phenol concentration value of 14 mg/kg in sediments as serious risks for the ecosystem (SRCeco). The maximum phenol concentration in the North-East Caspian Sea is four times lower than the SRCeco. As already mentioned, the Dutch criteria and, specifically MPC, can only be

Table 5.2-2 Comparison of average metal and arsenic concentrations (mg/kg) in North Caspian bottom sediments according to data from a range of sources, 1998 - 2016

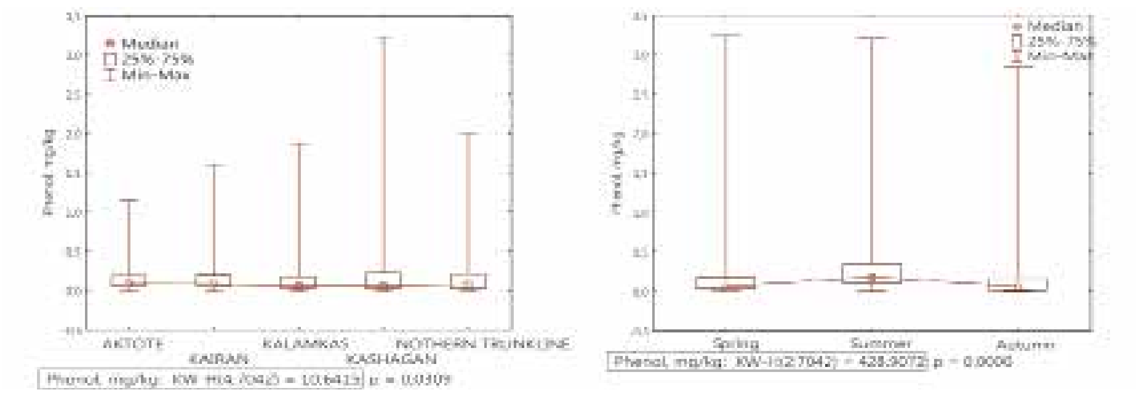
Element	ЛУLUKOIL 1998–2009 (Review, Astrakhan, 2016 a)	Caspian Ecological Programme, 2000 (de Mora, et al., 2004)	Rosgidromet, 2012–2014 (Review, Astrakhan 2016, a)	LUKOIL, 2016 (Review, Astrakhan, 2016, b)	LUKOIL, 2016 (Review, Astrakhan, 2016, c)	Company reports, 1996–2006 (Monitoring, 2014)	Company reports 2006–2010 (Reports 2006–2010)	Company reports, 2011–2016 (Reports 2011–2016)
	Range	Average	Range	Average	Average	Average	Average	Average
Al	n/a	17,100	n/a	n/a	n/a	n/a	2,648	2,733
As	n/a	4.13	n/a	n/a	n/a	2.84	1.5	2.7
Ba	0–3,060	293	n/a	337.5	200.3	154.9	62.6	62.8
Cr	n/a	31.4	n/a	n/a	n/a	8.8	8.6	6.3
Cu	0–70	6.4	3.7–54.8	12.2	2.0	5.8	4.4	3.7
Fe	0–25,500	6,730	0–16,750	6,277.3	5,865	4,543.5	2,821	2,766
Ni	0–48	10.4	3.3–54.2	17	8.65	11.3	16.8	11.6
Pb	0–35	5.75	0.6–32.3	12.7	1.03	6.2	2.4	2.6
V	n/a	20.4	n/a	n/a	n/a	23.3	9.1	9.8
Zn	0–226	11.1	1.1–166	26.6	10.4	17.7	9.4	8.3

Note: *n/a – data not available*

Table 5.2-3 Average organic compound concentration in North-East Caspian bottom sediments in 2006–2016 (n — number of observations, m — error of mean, SD — standard deviation)

Site	n	Mean. ±m	Median	Min.	Max.	SD
North-East Caspian Sea						
Total PAH, mg/kg	2,634	16.06±0.69	9.0	1.0	838.2	35.41
THC, mg/kg	6,912	3.75±0.05	3.0	0.05	114.3	4.22
Phenols, mg/kg	7,042	0.18±0.003	0.06	0.001	3.23	0.29
Kashagan						
Total PAH, mg/kg	1,804	14.92±0.76	9.0	1.0	838.2	32.32
THC, mg/kg	5,033	3.58±0.05	2.9	0.05	77.2	3.82
Phenols, mg/kg	5,108	0.19±0.004	0.06	0.001	3.23	0.31
Oil Field Pipeline						
Total PAH, mg/kg	228	20.8±1.66	12.0	1.0	203.0	25.03
THC, mg/kg	517	4.46±0.19	3.5	0.05	37.31	4.25
Phenols, mg/kg	519	0.19±0.012	0.08	0.001	2.01	0.28
Kalamkas						
Total PAH, mg/kg	194	17.15±1.02	13.0	1.0	93.0	14.24
THC, mg/kg	505	3.54±0.19	3.15	0.05	78.5	4.2
Phenols, mg/kg	506	0.14±0.01	0.06	0.001	1.87	0.22
Kairan						
Total PAH, mg/kg	193	24.63±5.65	11.0	1.0	661.0	78.45
THC, mg/kg	409	4.84±0.41	3.54	0.05	114.3	8.24
Phenols, mg/kg	425	0.15±0.01	0.08	0.001	1.6	0.2
Aktote						
Total PAH, mg/kg	215	11.94±0.79	9.0	1.0	117.0	11.58
THC, mg/kg	448	4.02±0.12	3.77	0.05	18.9	2.44
Phenols, mg/kg	484	0.15±0.008	0.08	0.001	1.14	0.18

Note: *Total PAH — total concentration of aromatic polycyclic hydrocarbons with 2–6 collars; THC — total hydrocarbon concentration*



A

B

Figure 5.2-5 Phenol content distribution by sites (A) and seasons (B) in North-East Caspian bottom sediments in 2006–2016 (under the Figures — Crascell — Wallis non-parametric test results showing the accuracy of median value differences)

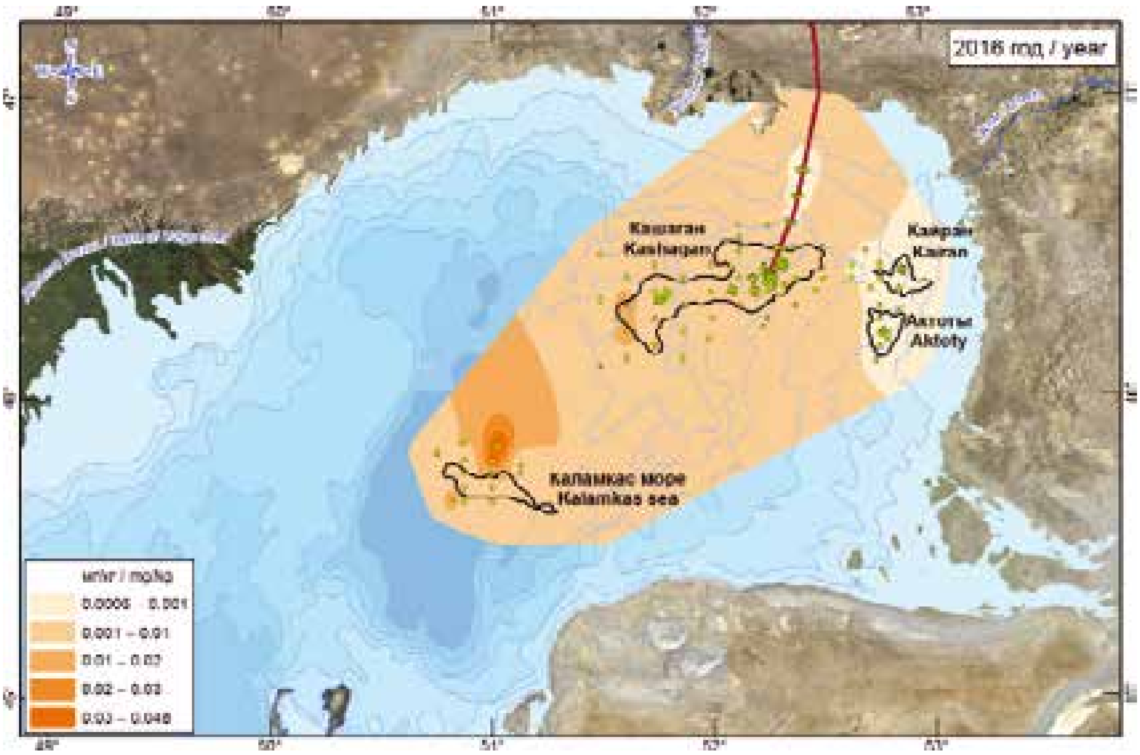


Figure 5.2.6 Phenol distribution in spring 2016.

used for a preliminary assessment of monitoring data.

Analysis of hydrocarbon assessment results for the 11 years is difficult because analytical laboratories, methods and equipment frequently changed during the period. The set of parameters to be analysed also changed. Only naphthalene and THC were measured regularly for the entire period. All other parameters were assessed occasionally, while only PAH out of the entire range of hydrocarbons were measured in recent years. The majority of certain measured hydrocarbons were present in the environment in concentrations that can be hardly defined, i.e. at the analytical zero level. Pollution levels are very clearly demonstrated in Table 5.2.4, where average and maximum concentration can be compared with international critical norms. The anthracene concentration at Aktote site reached 35% of the MPC only once, in autumn 2015.

The referenced international norms can be applied to the Caspian Sea conditions only tentatively. They were developed for a specific list of water bodies and for a specific type of sediments. For example, Dutch rates are applicable for bottom sediments containing 10% of organic substances and 25% of pelite, while this type of soil is not available in the water body under survey.

Changes in the content of hydrocarbons well represented over time are shown in Figure 5.2.7, while the distribution of parameters by observation site is shown in Table 5.2.3 and Figure 5.2.8.

High concentrations were recorded a number of times, however, there are no negative trends. The total concentration of polycyclic aromatic hydrocarbons with 2–6 collars and the total concentration of hydrocarbons changed insignificantly from site to site. The highest average PAH and THC concentrations were noted at the shallow coastal Kairan field (Table 5.2.3). Kashagan, recorded increased PAH concentrations in spring 2009 (Figure 5.2.7 B) (6 changes in the range of 0.3–0.9 mg/kg). These concentrations, compared to other measurements, are high, but much lower than critical levels, for example, the mean range of impact may be determined as 44.792 mg/kg [NOAA, 1999]. A comparison of the contemporary mean PAH content (16.06±0.69 mg/kg) against findings from an autumn survey

Table 5.2-4 Average and maximum PAH concentrations in bottom sediments in the North-East Caspian Sea in 2006–2016 (n — number of observations, m — error of mean); international norms for sediments pollution

Element	n	Mean. ±m	Max.	Dutch rates* SRC$_{eco}$	Dutch rates* MPC	Ecotoxicological norms (EAC) OSPAR** Upper limit	Ecotoxicological norms (EAC) OSPAR** Lower limit
Benzpyrene, mg/kg	1891	0.83±0.003	1.5	28,000	190	1,000	100
Naphthalene, mg/kg	3719	0.93±0.005	7.7	17,000	120	500	50
Anthracene, mg/kg	1084	0.83±0.03	13.6	1,600	39	500	50
Benzoanthracene, mg/kg	1084	0.703±0.001	1.5	49,000	490	1,000	100
Benzo(ghi)perylene, mg/kg	1084	0.701±0.0005	1.0	33,000	570	-	-
Benzo(k)fluoranthene, mg/kg	1084	0.703±0.003	1.5	38,000	380	-	-
Chrysene, mg/kg	1084	0.702±0.001	3.0	35,000	8,100	1,000	100
Phenanthrene, mg/kg	1084	0.71±0.003	1.9	31,000	3,300	1,000	100
Pyrene, mg/kg	1084	0.71±0.003	3.6	-	-	500	50

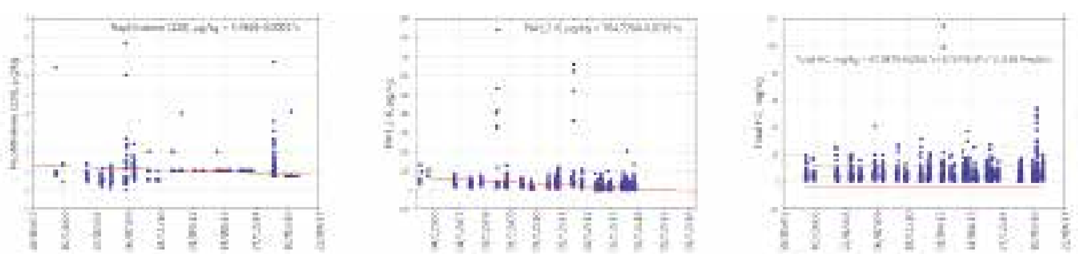
Note: ** - according to [Verbruggen, 2000]; ** - according to [OSPAR 2004]; SRCeco – Serious Risk Concentration for Ecosystems; EAC – Ecotoxicological Assessment Criteria*

in 2000 — 13.90±1.19 mg/kg according to [Tolosa,2004] (exclusive of deep water and Ural stations) shows, inclusive of the error of mean, a very small increase in content. The second increase in the PAH concentration to 0.35 – 0.7 mg/kg in spring 2012 (Figure 5.2.7 B) was only seen at Kairan field (4 measurements).

Geochemical markers are used to identify the origin of pollutants. The ratios set forth in Table 5.2-5 play a benchmarking role in this study. Furthermore, the percentage composition of aromatic hydrocarbons of the naphthalene, phenanthrene and dibenzothiophene layer (NPD total, %), which are sustainable products used in oil and petroleum product degradation, have been determined. NPD levels reduce when the stable NPD fraction is diluted by unstable (fresh) PAH.

The overall picture of the distribution of CPI across the water basin confirms the fact that majority of observations, 275 out of 337 for C_{12}-C_{20} and 286 out of 337 for C_{21}-C_{36}, indicate a biogenic or unspecified hydrocarbon composition (Figures 5.2.9 A and B). The CPI has been lower twice, in autumn 2008 and spring 2011, than the threshold value, which allows to assume that petrogenic hydrocarbons enter the sediment. The ratio is lower at all sites where material was collected. The mean value of CPI for a complete range of carbon C_{12}-C_{36} and for the entire surveyed water body of the North-East Caspian Sea, according to our data, amounted to 4.14±0.115, and according to data from a survey in 2000, somewhat higher at 5.73±0.335 according to [Tolosa, 2004], excluding deep water and the Ural stations.

The specific percentage value of NPD content shows a wide range of results — from 1 to 100% (Figure 5.2.9 C). The wide range of variations confirms the permanent existence of PAH source, however, does not indicate its nature. A change in the composition of the plankton community (with



A B C

Figure 5.2.7 Changes in naphthalene (mg/kg) (A), total PAH (mg/kg) (B) and THC (mg/kg) (C) in 2006–2016 at the North-East Caspian Sea basin

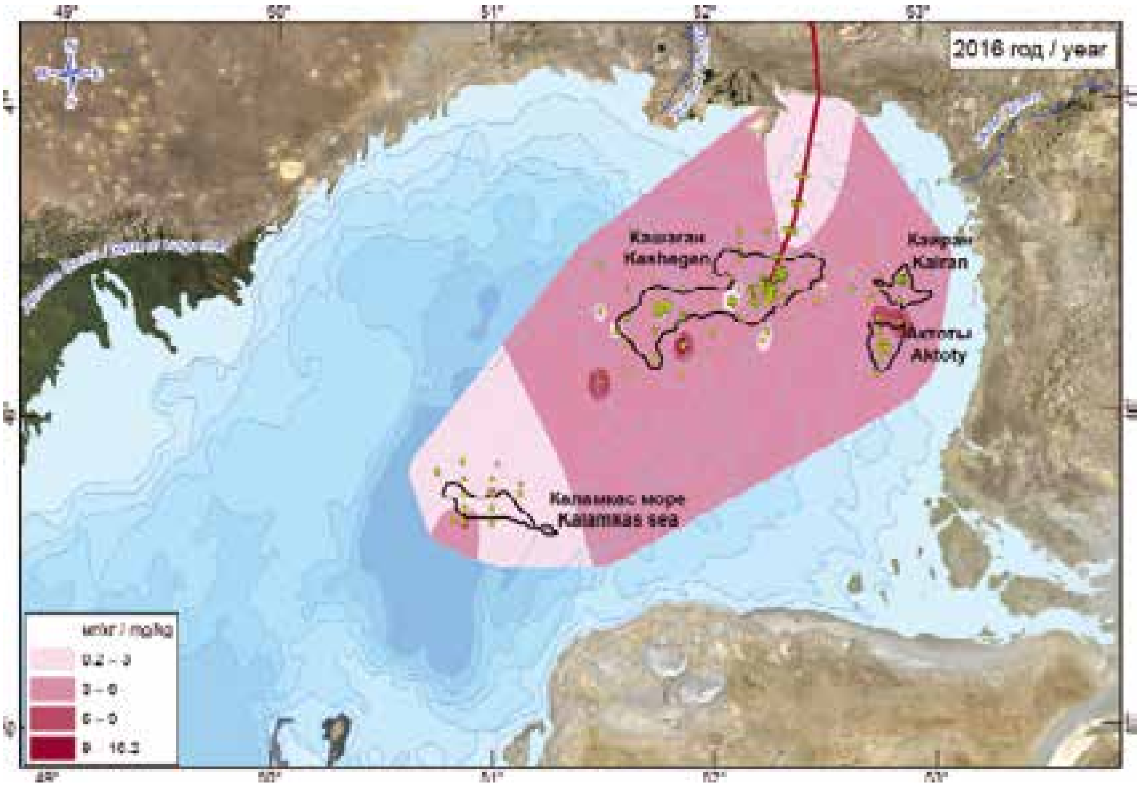


Figure 5.2.8 Distribution of total hydrocarbon concentration in spring 2016

Table 5.2-5 Tracer values of comparative data for hydrocarbon sources

Index (ratio)	Dominance of petrogenic hydrocarbons	Undefined composition of hydrocarbons	Dominance of pyrogenic or biogenic hydrocarbons
Carbon preference index (CPI)	Less than 1	1–4	More than 4
Pristane/phitane	Less than 0.9	0.9–1.1	More than 1.1
Phenanthrene/anthracene	More than 10	≈ 3 for wood and coal combustion	Less than 10
Anthracene/(phenanthrene+anthracene)	Less than 0.1		More than 0.1
Fluoranthene/Pyrene	Less than 1	Less than 1.0 timber combustion Less than 1.4 coal combustion	More than 1
Fluoranthene/(fluoranthene+pyrene)	Less than 0.5	0.4–0.5 liquid fuel and machine oil	More than 0.5
Value of pyrene and fluoranthene against chrysene and phenanthrene	Less than 0.5		More than 0.5

Note: *thresholds according to: [Brandli, Bucheli, 2007; M Sakari, 2012.; Santos, 2017; D Ţigănuş, 2013; Yunker, 2002]; the carbon preference index is the ratio of concentrations of n-alkalanes with an odd number of carbon atoms in a molecule against "even" n-alkanes*

the build-up of sinking and dead seston) can be considered as a PAH source. Minimum median and mean CPI values were recorded in May–June 2012.

The ratio between the pristane and phitane content in oil (isoprenoid hydrocarbons) is one of the genetic indices containing information on the properties of the initial composition. It is assumed that in extremely restorative conditions in the carbonate water column, which is common for the water bodies under study, pristane is dominated by phitane. These circumstances make the genetic context of this index unclear. However, a lot of data has been accumulated (337 findings), which are worth analysing. In one water basin alone, i.e. the Oil field pipeline routes, the pristane/phitane ratio clearly shows less critical values (a mean of 1.30 and median of 0.74). Low values prevail across practically the entire pipeline route, irrespective of construction activity. On the whole, it can be assumed that the pristane/phitane ratio indicates predominance of a biogenic component in bottom sediments hydrocarbons (Figure 5.2.9 D).

The anthracene/(phenanthrene+anthracene) ratios and the ratio of pyrene and fluoranthene to the chrysene and phenanthrene value are universal and are constantly indicative of the non-petrogenic origin of PAH. The fluoranthene/(fluoranthene+pyrene) ratio in this study turned

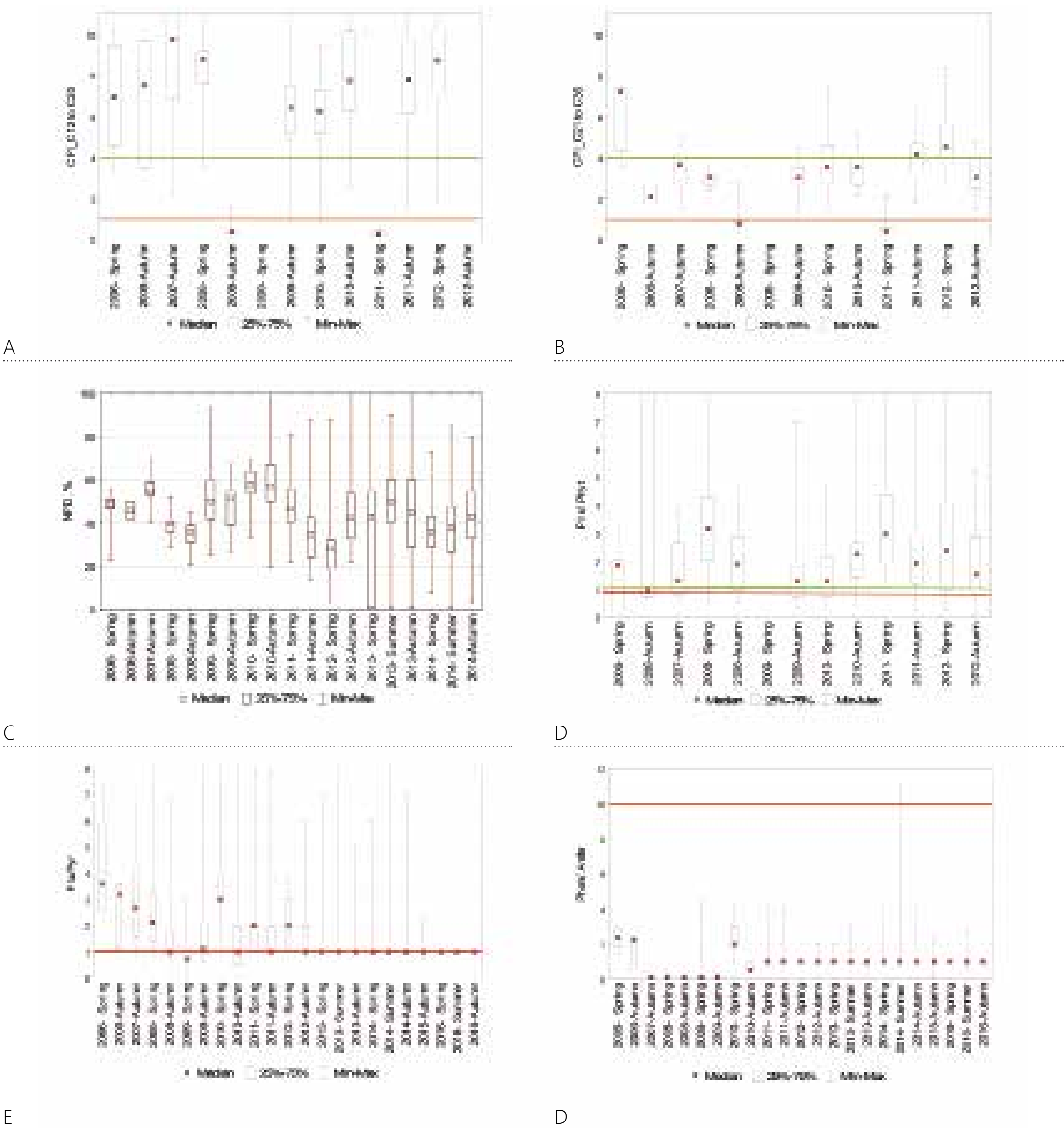


Figure 5.2.9 Changes in CPI for the C12-C20 (A) and C21-C36 (B) levels, the NPD (C) percentage, pristane/phitane (D), fluoranthene/pyrene (E), and phenanthrene/anthracene (F) ratios; horizontal lines are critical borders; A, D and E are low-value hydrocarbon areas

out not to be indicative, because out of 1,084 measurements, only 15 measurements were above 0.5 and 3 were below 0.5 (0.5 is the threshold index in Table 5.2.5).

In the water body under study, a phenanthrene/anthracene ratio of over 10 was found only once in summer 2014, on the Oil field pipeline route (Figure 5.2.9 F). However, some authors believe that the phenanthrene/anthracene ratio is a less reliable indicator when identifying the nature of hydrocarbons.

The fluoranthene/pyrene ratio provides more accurate results. However, out of 4,526 measurements taken, only 413 showed a value that differed from the unit of measurement. The mean value of these 413 measurements is 2.55±0.13, which indicates predominance of pyrogenic and biogenic hydrocarbons. At Kashagan, 54 out of 3,180 measurements (or out of 264 measurements that differed from the unit of measurement), the fluoranthene/pyrene ratio pointed to the existence of hydrocarbons in oil-generated sediments. This occurred in 2008–2010 (Figure 5.2.9 E), when a range of simultaneous operations were conducted at the site, such as island construction, laying of pipelines, assembly work and well drilling. Later on fluoranthene/pyrene has stabilised.

5.3 Impact of Man-caused and Natural Factors on Bottom Sediments Characteristics

The Caspian Sea is a highly productive water body characterized by its biodiversity and its significant oil and gas reserves [Appolov, 1956; Ivanov, 2000; Salmanov, 1999; Peeters et al., 2000]. The closed and inland location of the Caspian Sea is the cause of high dependence of the water body environment on external factors [The Caspian Sea, 1989]. Both natural and man-caused factors have impact on composition and quality of bottom sediments.

Bottom sediments are a part of the marine ecosystem – a biotope or series of biotopes with different abiotic characteristics. Bottom sediments represent a complex multi-component system and have a great impact on functioning of the marine ecosystem. Monitoring of the condition of bottom sediments allows not only revealing pollution, but also assessing nutritional conditions (feed stock) and the status of bottom-feeding fish populations. Contrary to the pollution of the water column, which is very dynamic over time and space, bottom sediments pollution is not so dynamic. Only a number of sediments characteristics show a seasonal element, often determined by a seasonal change in biological processes.

Sediments formation in the Caspian Sea is influenced by a number of factors. The most important are hydrodynamic factors such as river inflow, currents and waves which facilitate transfer, sorting and distribution of sediments. Climatic conditions, coastal geomorphology, bottom topography, calcium carbonate deposits and others have also impact on the sediment formation process.

FLUCTUATIONS IN THE SEA LEVEL AFFECT BOTTOM TOPOGRAPHY AND THE DISTRIBUTION OF SEDIMENTS IN THE NORTHERN, ESPECIALLY IN NORTH-EASTERN SHALLOW PARTS OF THE CASPIAN SEA.

Hydrochemical conditions also greatly influence the origin of sediments. The high carbonate content in the Caspian Sea, the large alkaline reserve and higher pH value facilitate an intensive carbonate precipitation process [Klenova, 1948; Lobkovskii et al., 2005]. The chemical composition of bottom sediments is primarily determined by the inflow of dissolved, suspended and bed load sedimentary materials from rivers [Strakhov et al., 1954; Khripunov, 1974; Khrustalyev, 1978]. Suspended substances and chemical elements in solution, which are actively involved in formation of bottom sediments, enter with river inflows into the North Caspian Sea from the Volga and Zhaiyk (Ural) Rivers. Major terrigenous suspended substances introduced into the sea with river inflow are deposited in the pre-delta zone. Fine suspended substances (less than 0.01 mm) are deposited in the open sea [The Caspian Sea, 1989; Khrustalyev. 1978].

Indigenous sedimentary materials are generated by virtue of the chemogenic creation of minerals, entry of biogenic plankton and benthos remainders [Khrustalyev, 1978]. Biogenic shelly soil is often formed in the North-East Caspian Sea together with an insignificant mixture of terrigenous material. The favourable hydrological and hydrochemical processes create good conditions for the development of bacteria, plankton and benthos organisms in the water body. Zooplankton in the digestion process consumes suspended matter, ingests both the organic and mineral parts, and then returns it in the form of activated clumps to the aquatic environment as sedimentary material. [Fowler et al., 1972; P Mayzand, S Poulet, 1978; S Poulet et al., 1973]. Zoobenthos organisms digest mineral and organic substances from the bottom water and sediments and expel agglutinates, forming sedimentary material [Khrustalyev, 1989]. Microorganisms play an important role in changes and generation of organic substances [Degens, 1967]. Bacteria facilitates decomposition of organic substances and the exchange of elements in the "soil – water" system [Khrustalyev, 1978]. The quantity of bacteria in a water body is determined by existence of available organic compounds, synthesised by phytoplankton and deposited together with river inflow [The Caspian Sea, 1985]. Suspended substances being a feedstock for creation of bottom sediments, have polygeneric composition and undergo significant changes in the water column till it is buried [Khrustalyev, 1978].

Man-caused pollution has had a significant impact on the marine ecosystem over a number of decades. The main sources of pollutants in the Caspian Sea are river inflow and atmospheric pollutants; industrial, domestic, household and agricultural discharges; navigation, oil and gas well operations; oil transportation by sea; coastal slopes wash and secondary pollution.

The impact of river inflow on the quality of sea water and bottom sediments is of both natural and man-caused nature. Natural characteristics include natural fluctuations in the water level of the rivers in the North Caspian basin, mostly due to climate change. Negative natural factors include hydrocarbon-related man-caused stress. It is worth noting that the man-caused impact on river ecosystems began long before the development of offshore fields at the end of the 20th century. First of all, it is associated with river inflow regulation and the pollution of the river water. The regions generating pollutants with river inflow are 90% concentrated in the North Caspian Sea. This ratio is traced almost for all parameters (petroleum hydrocarbons, phenols, synthetic surfactants (SSAS), organic substances, metals and others). It is worth noting that a relatively large proportion of river pollutants tends to decrease, however, to a less extent because of reduced production in river catchment basins, and to a greater extent because of growth in offshore oil production.

The intensive development of offshore oil production increases a man-caused impact on the marine ecosystem. Analysis of international practice in development of offshore oil and gas fields shows that even under routine oil production conditions, each drilling rig is a source of many pollutants, whether in solid, liquid or gaseous forms. This problem is especially acute in the shallow parts of the Caspian Sea.

Increase in hydrocarbon production results in intensification of navigation. Water transport is also a source of pollution in the Caspian Sea, due to potential leakage of fuel, bilge water and ballast water. Atmospheric emissions and the generation of solid waste also needs to be taken into account.

Furthermore, intensive navigation in shallow parts of the Caspian Sea results in high turbidity of silty bottom sediments and the redistribution of fine fractions that are the main sorbents of pollutants (hydrocarbons and many metals).

Secondary pollution is related to fluctuation of the Caspian Sea level. The major potential threats to the Caspian ecosystem are oil fields located in the flooding and underflooding zones. According to different assessments there are more than 600 flooded wells in pre-Caspian regions. They include about 100 ownerless wells that do not belong to subsoil users. [Kereibayeva et al., 2013].

A SIGNIFICANT VOLUME OF DATA WAS ACQUIRED DURING ENVIRONMENTAL MONITORING STUDIES IN THE NORTH-EAST CASPIAN SEA IN 2006–2016. ALMOST ALL DATA CONFIRMS ABSENCE OR SHORT-TERM AND MINOR IMPACT OF THE COMPANY'S OFFSHORE FACILITIES

Surface bottom sediments in the majority of water bodies under study were mostly represented by different sized terrigenous and carbonate sand. Finer sediment structure in specific water bodies was determined most frequently by natural sedimentation processes and granulometric differentiation with bathymetry, hydrodynamics and lithodyanimcs, and the composition of sediment material inflow being determining factors.

The granulometric composition of sediments in water bodies under study is sufficiently conservative and does not undergo evident changes without significant external influence, such as dumping. Impact related to ongoing construction activities in Kashagan field has not caused noticeable changes in the granulometric composition of bottom sediments.

In the period of 2006 – 2016, the picture of the distribution of the total content of organic substances in sediments was relatively unchanged. The distribution of Eh values in 2006–2016 on the surface and subsurface layers of bottom sediments indicates a practically universal dominance of anaerobic and moderately anaerobic conditions. Seasonal changes in reduction-oxidation potential were found practically at all water bodies to this or that extent, probably due to the seasonal changes in temperature.

In the period of 2006 – 2016, the spatial pattern of sediment pollution with metals remained relatively unchanged. Aluminium and related core terrigenous metals undergo periodical variations, but only very rarely exceed international OSPAR rates, and only in some samples. The majority of metals are closely linked to fine sediment fractions. Mercury and cadmium are usually present in trace quantities.

Due to the specific nature of the North-East Caspian Sea, aluminium, barium and iron are always found in significant quantities. There is no evident relation of commercial and operational activities with metal content in bottom sediments. A percentage of barium originates from the use of its salts in drilling mud. The high barium concentration at the Aktote and Kairan fields, where drilling operations were completed almost 10 years ago, may be explained by sheet erosion and wind gain from coastal fields.

The increase of nickel concentrations in sediments can be caused by onshore production of oil enriched by metals (vanadium and nickel). No increase in vanadium in sediments was noted. Nickel accumulation does not occur in deeper water outside the wave impact area. Higher concentration of terrigenous metals are recorded in shallow waters.

The location of sampling points has practically no impact on phenol content, which means natural and indigenous predominance of phenols and absence of any relation to man-caused sources and the coast. Phenol concentration in bottom sediments for the entire North-East Caspian water body is stable or reduces over time. Organic substance concentration slightly decreases over time.

The range of variation in hydrocarbon content in bottom sediments is high. For the entire North-East Caspian water body, hydrocarbon concentration is stable. Critical (indicatory) limits are rarely exceeded. There is no chronic pollution.

The overall picture of CPI distribution and the pristane/phitane ratio across the water body indicates a biogenic or undefined composition of hydrocarbons in bottom sediments. In the area of Oil field pipeline routes, the pristane/phitane ratio indicates a practically combined or petrogenic hydrocarbon composition, irrespective of construction activities.

Application of a series of PAH genesis ratio/indicators shows predominance of igneous and biogenic hydrocarbons. Certain indicators point to the possible inflow of petrogenic hydrocarbons in 2008–2010 (Kashagan) and in 2011–2012 (other water bodies).

Ongoing operations related to development of oil and gas fields in Kazakhstan sector of the North Caspian Sea will probably not cause any noticeable changes in the structural characteristics and chemical composition of surface level bottom sediments in absence of dredging and soil dumping operations, and oil spills.

Bottom sediments at the actively developed Kashagan field can be considered as relatively clean regarding metal and hydrocarbon content. No chronic pollution with respect to any parameters under study has been revealed.

5.4 Proposals to Minimise Negative Impacts

Five independent States are located on the Caspian Sea coast, and all of them have sufficiently developed oil and gas industries producing crude oil, both onshore and offshore.

Because pollutants can migrate over sufficiently large water body, and because the ichthyofauna and avifauna, and seals migrate, environmental issues of the Caspian Sea are important for all Caspian States. Any, even minor incidents, pollutant emissions and discharges into the sea in one region can have a negative impact on the entire Caspian ecosystem and, consequently, on the Caspian States.

The development of offshore and onshore oil and gas facilities will probably only grow, which will lead to increases in the number of marine pollution sources. To reduce and eliminate the potential negative consequences of man-caused impact, a number of measures need to be taken to protect the environment:

— Oil and gas companies shall strictly follow environmental legislation requirements.

— High technologies and modern equipment shall be used in performance of any offshore activities (exploration, construction, production, processing and products transportation) to prevent any emergencies. It is necessary to have emergency response plans in place.

— Navigation shall be reduced to minimum. Vessels with shallow draft shall be used.

— Flaring of associated and process gas at oil and gas facilities shall be reduced.

— Collection, disposal, decontamination and burial of industrial waste shall be improved. It is necessary to envisage closed operational cycles, reduction of power consumption, use of recycled materials and energy resources.

— Ownerless and flooded offshore and onshore wells shall be abandoned.

— It is necessary to develop common environmental requirements to oil and gas projects in the Caspian Sea region for all Caspian States.

— Regular and comprehensive environmental studies shall be performed at all stages of offshore operations. Annual monitoring should be performed at the same time with application of similar methods for all oil and gas facilities in the North Caspian Sea. To resolve this issue, a bilateral agreement between Kazakhstan and Russia is required to ensure environmental control over offshore oil fields in the North Caspian Sea. This agreement can facilitate development of common requirements to environmental monitoring; allow performance of joint environmental expert reviews of offshore projects and exchange of experience. Furthermore, joint emergency response exercises at offshore facilities can be conducted.

Conclusions

Generally, the quality of bottom sediments in the North-East Caspian Sea in terms of metal and hydrocarbon content is characterised as satisfactory.

Chronic pollution and changes in physical and mechanical characteristics as a result of fixed sources impact have not been revealed for all parameters under study.

Metal concentration in the bottom sediments of the North-East Caspian Sea does not exceed permissible levels (except for certain samples at some stations).

The range of hydrocarbon content variation in bottom sediments is high. The concentration of hydrocarbons in the North-East Caspian water body is stable. Pyrogenic and biogenic hydrocarbons dominate. Exceedence of critical levels or indicative values is very rare.

Possible change in analytical laboratory or test methods at those laboratories shall be taken into account when analysing and interpreting monitoring data.

Thus, only a comprehensive approach to environmental issues by all Caspian States and close cooperation of state regulators, industrial enterprises and environmental companies can help to reduce negative consequences of intensification in development of offshore oil and gas sector.

6. PHYTOPLANKTON

Material under study and methods

In 2006 and in 2008-2012, phytoplankton surveys were conducted in spring and autumn, in 2007 — only in autumn, from 2013 to 2016 — in spring, in summer and autumn [Reports, 2006-2016]. As a whole during the period from 2006 to 2016, 2,434 samples of phytoplankton were collected (Table 6-1).

Phytoplankton samples were taken and processed according to general standard methods [Methodological Recommendations, 1981, Fedorov, 1979].

Phytoplankton samples were taken from the trophogenic water layer which depth is considered equal to the tripled depth of transparency measured on the basis of Secchi disk. To obtain a composite sample one liter of water was taken by bathometer starting from the surface and further every other meter. The water samples were put into a large-volume container. Then a liter of sub-sample was taken from the carefully mixed composite sample for further analysis. The sample was preserved with 4% formalin solution.

Plankton algae species were identified according to the classifier [Ergashev, 1979a, 1979b, Proshkina-Lavrenko, Makarova, 1968, Kisselev, 1954, Zabelina, 1951, Gollerbach, 1953, Diatoms, 2002].

Phytoplankton cells were counted in Goryaev's chamber. The individual cell mass was determined by the estimation method, multiplying the cell volume by the density. The cell volume was equal to the volume of known geometric figures, the water density was considered equal to 1.

The classification was aligned with the accepted nomenclature [Guiry & Guiry, 2018].

Average annual and average long-term annual values of abundance and biomass were estimated based on the longest data sequence: 2006, 2008-2016 spring and autumn surveys.

AVERAGE SEASONAL VALUES OBTAINED IN SPRING, SUMMER AND AUTUMN OF 2013-2016 WERE USED TO DESCRIBE OVERALL SEASONAL DYNAMINCS OF PHYTOPLANKTON.

The data of sample analysis was included into the general database using the Biota software [Intellectual Property Certificate, 2017]. Further data processing was carried out with use of Excel spreadsheets, software Primer v6 [Clarke, Gorley, 2006] and «Statistica».

Table 6-1 Number of phytoplankton samples taken in 2006-2016.

Region	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Aktote	0	0	0	0	0	8	6	32	33	33	15	127
Kairan	0	0	0	0	0	8	5	27	27	22	12	101
Kalamkas	1	10	20	21	26	24	6	50	72	58	27	315
Kashagan	154	33	147	101	194	121	126	213	213	224	145	1590
Oil field pipeline	19	18	18	10	16	16	13	32	28	16	34	201
Total	**174**	**61**	**185**	**132**	**236**	**177**	**156**	**354**	**373**	**353**	**233**	**2434**

6.1 Species Richness

Phytoplankton composition included 503 algae species, namely, blue-green *(Cyanobacteria)* — 100, diatoms *(Bacillariophyta)* — 265, pyrophytic and dinophyte *(Miozoa)* — 25, ochrophytic *(Ochrophyta)* — 2, green *(Chlorophyta)* — 98, *Euglenozoa* — 13 (Table 6.1-1). The number of plankton algae species varied from 103 to 313 throughout the years. During the survey period, there was an increase in the abundance of revealed species with a peak in 2013, followed by its decrease by 2016. Changes in the number of microalgae species by years depend on the number of species sampling at each station, as well as the frequency of observations. The increase in species abundance in 2011-2013 is related to the increase in the number of observations, as well as to the fact that since 2013 sampling has been conducted in spring, summer and autumn.

The most common species were *Anathece clathrata*, *Lyngbya limnetica*, *Merismopedia minima*, *Merismopedia punctata* in the blue-green algae, *Cyclotella choctawhatcheeana*, *Cyclotella meneghiniana in diatoms*; *Binuclearia lauterbornii* in the green algae (Annex 4, Table A1). During the period under review the occurrence frequency of certain species varied significantly. Thus, *Ankistrodesmus arcuatus* widespread in 2007-2009, was found less often in the subsequent years. The blue-green algae *Gloeocapsa minuta*, *Oscillatoria amphibia* and diatom *Navicula salinarum* were most widely distributed in the middle of the observation period, whereas at the start and end of this period the number of their occurrence was significantly lower. For other species, such as the blue-green *Gloeocapsa minima*, *Lyngbya contorta*, *Spirulina laxissima*, diatoms *Amphora coffeaeformis*, *Cylindrotheca closterium*, *Diploneis Smithii*, green *Monoraphidium contortum*, the occurrence frequency increased by the end of the observation period.

Species richness of phytoplankton varied considerably at different sites of the surveyed water area. One of the factors determining the number of algal species was the number of surveys. Thus, the most surveyed area is Kashagan field with a much higher number of analyzed samples as compared to other locations (Tables 6.1-1 and 6.1-2). The number of phytoplankton species found there was the highest.

At the same time, it should be noted that phytoplankton species richness was changing disproportionately to the observations number. The number of samples analyzed from other locations was from 5 to 16 times lower than in Kashagan, however, the number of revealed species of planktonic algae was lower maximum by 2 times. Based on assessment of the number of species of phytoplankton found in the area against the number of analyzed samples, it can be concluded that the

Table 6.1-1 Year-to-year dynamics of phytoplankton's species richness in the North-East Caspian Sea in 2006-2016.

Section	2006 -2016	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cyanobacteria	100	29	23	28	38	34	34	49	63	62	62	52
Bacillariophyta	265	62	50	67	74	99	100	111	169	152	170	134
Miozoa	25	7	8	7	6	10	12	9	15	16	17	15
Ochrophyta	2	0	0	1	0	1	1	1	1	1	1	0
Chlorophyta	98	18	20	22	31	29	37	35	58	52	46	34
Euglenozoa	13	2	2	1	3	2	3	3	7	8	4	3
Total	**503**	**118**	**103**	**126**	**152**	**175**	**187**	**208**	**313**	**291**	**300**	**238**

Figure 6.2.1 Dynamics of quantitative values of phytoplankton in the North-East Caspian Sea in 2006-2016.

Region	Cyanobac-teria	Bacillario-phyta	Miozoa	Ochro-phyta	Chloro-phyta	Eugle-nozoa	Total
Aktote	64	148	17	1	68	4	302
Kairan	54	129	15	1	54	6	259
Kalamkas	57	147	21	1	46	9	281
Kashagan	93	262	26	2	100	10	493
Oil field pipeline	73	194	17	1	75	6	366

HIGHEST SPECIES RICHNESS IS TYPICAL FOR THE SHALLOWER AND BIOTOPICALLY DIVERSE REGIONS — AKTOTE, KAIRAN, OIL FIELD PIPELINE, WHILE THE LOWEST SPECIES RICHNESS WAS IN THE AREAS WITH LARGER DEPTHS AND MORE MONOTONOUS ENVIRONMENTAL CONDITIONS, SUCH AS KALAMKAS FIELD.

6.2 Quantitative variables

The average long-term abundance of phytoplankton was 900.8 million cells/m^3 (Annex 4, Table A2). Blue—green algae were dominant (84.5% of the total number). The proportions of other groups were as follows: green — 8.9%, diatoms — 6.4% and others — less than 0.2%. The average long-term value of biomass reached up to 616.0 mg/m^3 (Annex 4, Table A3). It was mostly composed of diatoms — 83.7% of the total value. The proportion of blue-green algae was 6.8%, pyrophytic and dinophyte algae — 4.9%, green — 4% of the community biomass. The contribution of ophophytic and euglenic was insignificant — no more than 0.3 %.

During the period under study there was an increase in the abundance of phytoplankton (Figure 6.2.1). The main contribution in increase of phytoplankton abundance was made by the blue-green (R = 0.991), diatoms (R = 0.800) and green algae (R = 0.772). The basis of abundance was composed of filamentous and colonial blue-green algae *L.limnetica*, *L. contorta*, *M.minima*, *M. punctata*, *A.clathrata*, *O.amphibia*. A very strong negative, statistically significant relation was found between the total plankton algae abundance and the average individual cell mass value (R = -0.927). The decrease in the size variable was mainly caused by blue-green algae (R = -0.936) in the periods of mass development of this group.

The dynamics of phytoplankton biomass also indicated a trend in increase till 2015, and a slight decrease in 2016 (Figure 6.2.1).

The growth of biomass by 75% was caused by development of diatoms (R = 0.754). In 2006-2007, the dominant phytoplankton complex included diatom species (*C.meneghiniana*, *Actinocyclus ehrenbergii*, *Coscinodiscus lacustris*), green (*B.lauterbornii*) and blue-green (*Gomphosphaeria aponia*, *Gomphosphaeria lacustris*) algae. In 2008-2010, there was a change in the phytoplankton polydominant complex with almost complete dominance of the diatom *Coscinodiscus jonesianus* in the biomass. Since 2015, *C.jonesianus* biomass had been declining, and dominance was shifting to diatoms: *Diploneis ovalis*, *A.ehrenbergii*, *Hyalodiscus sphaeroiphorus*.

Spatial distribution

The average seasonal abundance of phytoplankton in Aktote field varied and reached its maximum of 3971.3 million cells/m^3 in the summer period. By autumn, the value had decreased to the average of 1,792.0 million cells/m^3. In spring, the phytoplankton abundance was minimal — 678.3 million cells/m^3. Blue-green algae *L.limnetica*, *L.contorta*, *M.punctata*, *Anabaenopsis cunnigtonii*,

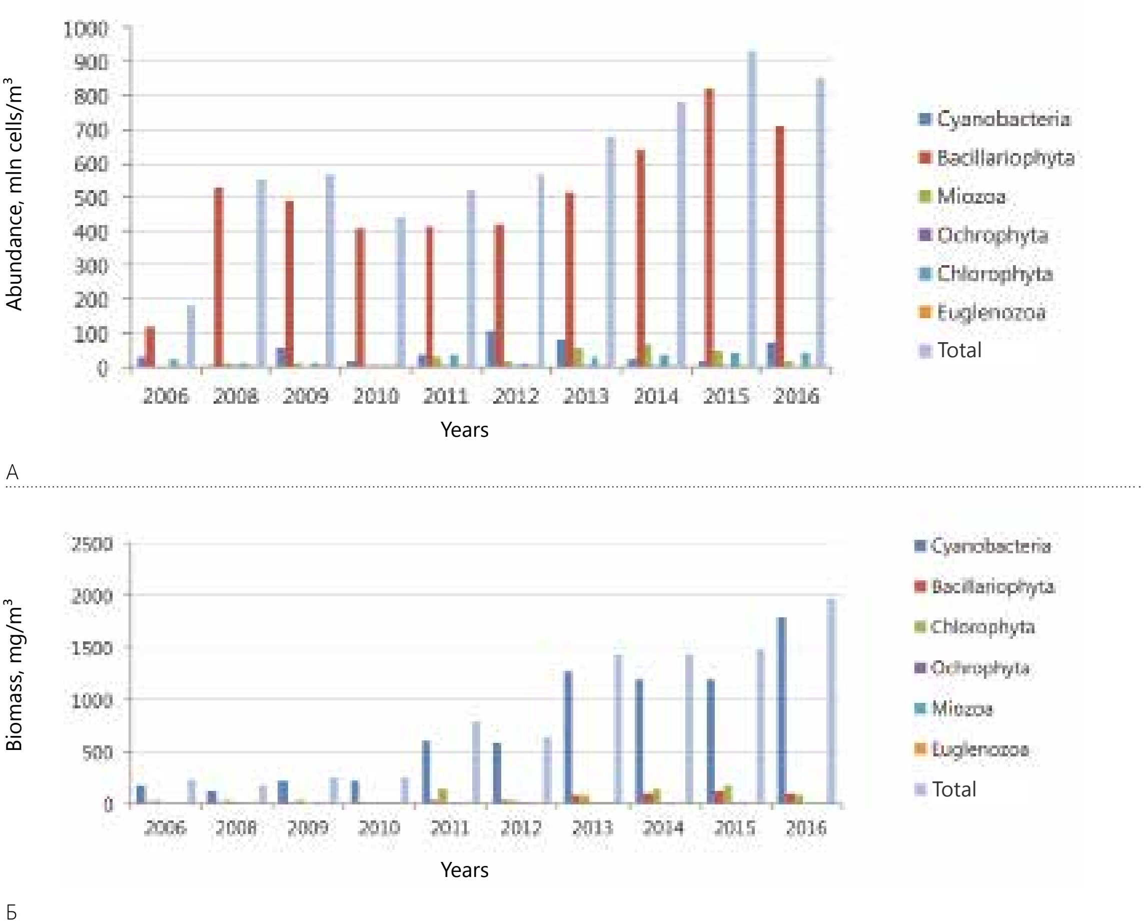


Figure 6.2.1 Dynamics of quantitative values of phytoplankton in the North-East Caspian Sea in 2006-2016.

G.lacustris dominated in abundance.

The total average biomass value of plant cells varied seasonally in relatively small ranges 807.2-1,015.5 mg/m^3, with the maximum value recorded in autumn. The main community biomass was formed by diatoms. In 2011-2015, the dominant biomass complex included such diatoms as *C.jonesianus*, *Thalassiosira incerta*, *Thalassiosira caspica*. In 2013-2014, the dominants included blue-green algae of the *Phormidium* type. In 2016, the dominance had shifted to diatoms *Campylodiscus clypeus*, *Campylodiscus daemelianus and D.ovalis*.

From the long-term perspective, the dynamics of quantitative variables for phytoplankton had its own seasonal specifics (Figure 6.2.2). In spring observation sequence, the highest phytocenosis abundance was recorded in 2011 and 2016. The summer phytoplankton maximum was recorded in 2014, and the autumn peak was recorded in 2013. The long-term dynamics of the phytoplankton biomass was characterized by unclear trend in decrease of this variable value in spring and a trend in increase in autumn.

The average abundance of phytoplankton at Kairan field increased from 734.6 million cells/m^3 in spring, up to 1,947.8 million cells/m^3 in summer and 2,117.5 million cells/m^3 in autumn (Figure 6.2.3). The blue-green algae dominated in abundance due to massive development of filamentous and colonial forms of *L. limnetica, L. contorta, Microcystis pulverea*.

The average total biomass of plant cells changed slightly over the seasons — 610.1-857.1 mg/m^3, with the peak value recorded in autumn. The main part of the biomass community was formed by diatoms. The main biomass dominant in 2011-2015 was a marine and brackish-water neritic species of diatoms *C.jonesianus*. In 2014-2015, the dominant species complex also included the

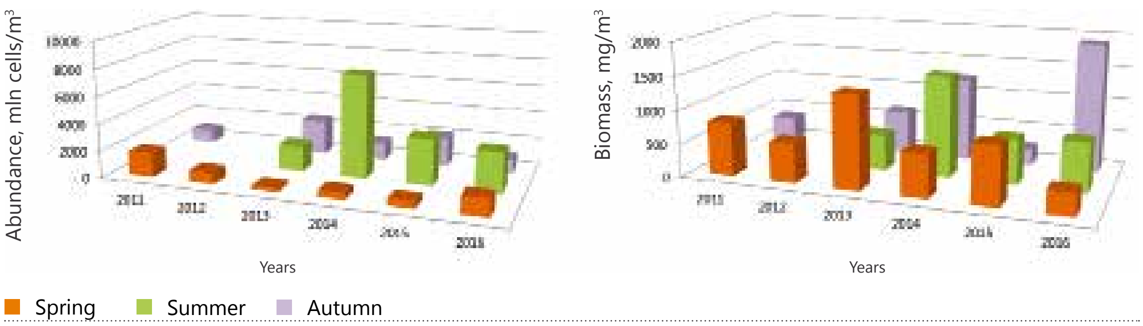


Figure 6.2.2 Seasonal and long-term dynamics of phytoplankton quantitative variables in Aktote field

diatom algae *Th.caspica*. In 2016, domination had shifted to *C.clypeus* and *D.ovalis* diatoms.

The long-term dynamics of phytoplankton abundance is described as a concave curve, with peak values in 2011 and 2016 (Figure 6.2.3). In summer, the value increased almost linearly in the analyzed time sequence, declined in the middle of the observation period in spring and autumn and increased again at its end. The long-term dynamics of phytoplankton biomass was characterized by unclear trend in decrease in the spring-summer period and an increase in autumn.

The average seasonal value of phytoplankton abundance in Kalamkas reached its peak value in summer averaging at 2,165.4 million cells/m^3. By autumn the community size decreased to the average value of 1,585.5 million cells/m^3. The spring period was characterized by a minimal abundance of plant cells – 1,230.6 million cells/m^3. Blue-green algae *L.limnetica*, *L. contorta*, *A.clathrata*, *O.amphibia* dominated in terms of abundance. The average seasonal value of biomass decreased from spring to summer from 624.7 mg/m^3 up to 583.1 mg/m^3 and decreased further to the autumn period to 534.9 mg/m^3. The main biomass community was formed by diatoms. The dominant composition complex included diatoms *C.jonesianus*, *Coscinodiscus gigas*, *C.meneghiniana*, *C.caspia*, *Pseudosolenia calcar-avis*, *Th.incerta*, *A.ehrenbergii*, *Thalassiosira nitzschioides*, *Entomoneis paludosa*, *Nitzschia sigma*, *H.sphaerophorus*. In 2006-2007, the polydominant complex also included green alga *B.lauterbornii*, blue-green *G.minuta* and pyrophytic *Glenodinium caspicum*. In 2014, pyrophytic algae *Prorocentrum scutellum*, *P.cordatum*, *G. caspicum* had contributed significantly into the phytoplankton biomass (up to 30%). It is worth noting that in 2008-2010 period the leading role in plankton as taken by marine and brackish-water species *C.jonesianus*, *C. gigas*, *Th.incerta*, *Th. nitzschioides and P. calcar-avis*.

All seasons demonstrated a trend in abundance increase in the second half of the period under study. Maximum values in abundance were observed in spring 2014, in summer 2015 and in autumn 2013. The phytoplankton biomass reached its peak values in spring 2015, in summer 2016 and in autumn 2011 and 2013. (Figure 6.2.4).

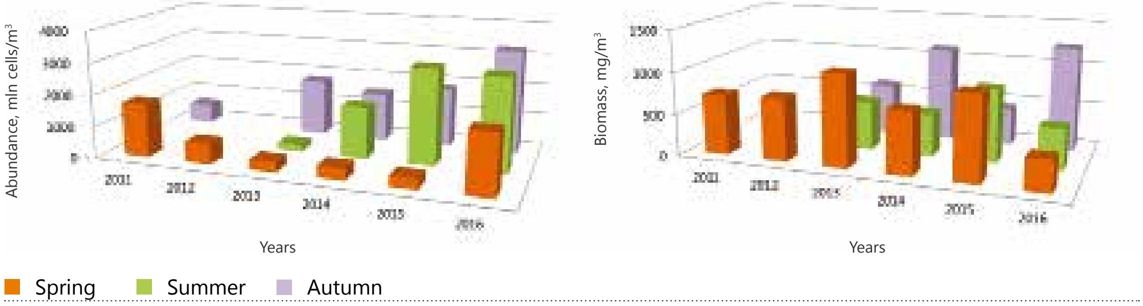


Figure 6.2.3 Seasonal and long-term dynamics of phytoplankton quantitative variable at Kairan field

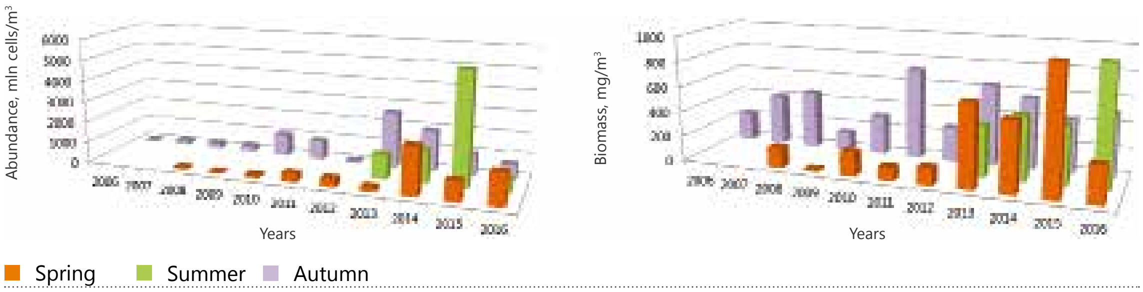


Figure 6.2.4 Seasonal and long-term dynamics of phytoplankton quantitative variables at Kalamkas field

The average value of phytoplankton abundance in Kashagan reached its maximum in the summer period – 2,397.3 million cells/m^3. By autumn, the variables value decreased to the average value of 2,019.3 million cells/m^3. In spring, the phytoplankton abundance was at the lowest level – 1,228.8 million liters/m^3. Blue-green algae dominated in abundance. The abundance was mainly composed of colonial and filamentous blue-green algae *L. limnetica*, *L. contorta*, *M.minima*, *M. punctata*, *A.clathrata*, *O.amphibia*.

The total phytoplankton biomass value reached its peak in spring averaging 877.0 mg/m^3, however in summer it decreased to 706.5 mg/m^3. In autumn, the minimum phytocenosis biomass values recorded were 616.7 mg/m^3. The main biomass community was formed by diatoms. In 2006-2007, the dominant phytoplankton complex included species of diatoms (*C.meneghiniana*, *A.ehrenbergii*, *C. lacustris)*, green *(B.lauterbornii) and* blue-green *(G.aponia*, *G. lacustris*) algae. In 2008-2010, there was a change in the polydominant complex almost for the entire dominance of marine brackish-water species of diatoms *C.jonesianus* in biomass [Diatom ..., 2002]. From 2015 *C.jonesianus* biomass has decreased with domination shifted to diatoms *D.ovalis*, *A.ehrenbergii and H.sphaerophorus*.

A long-term trend in increase of phytoplankton abundance in all seasons in the second half of the described period was determined. In spring, the maximum average values of phytoplankton were recorded in 2016, in summer 2015, in autumn 2013 and in 2015. (Figure 6.2.5). The phytocenosis biomass dynamics in different seasons was not similar. In spring and summer it was related to the quantity dynamics, with a maximum in 2015. In autumn 2007, the maximum values of phytoplankton biomass were recorded in the first half of the period under study.

Kashagan field area differs both by the largest number of surveys conducted and by the most intensive operations. Intensive hydrotechnical construction works were carried out in Kashagan East water area. Impact of mineral suspensions resulted in local changes in chemical characteristics of the water and its transparency. This, in its turn, had an impact on structural and functional characteristics of hydrobionts communities, especially microalgae, whose vital activity directly depends on the biogenic element concentration and the degree of light penetration into the water column. In 2010, drilling and construction activities in Kashagan area were completed. It is quite possible that stop of impact resulted in the growth of microalgae abundance since 2011.

The average phytoplankton seasonal abundance along the Oil field pipeline routes increased from 1,061.6 million cells/m^3 in spring up to 3,517.6 million cells/m^3 in summer and declined in the autumn period to 2,514.7 million cells/m^3. Blue-green algae dominated in quantity, mainly due to development of colonial and filamentous forms of *L.limnetica*, *L. contorta*, *A.clathrata*, *O.amphibia*, *M.pulverea*.

The total average value of plant cells biomass had a minor variation by seasons, i.e. 1,156.1-1,660.9 mg/m^3, with the maximum value recorded in summer and close values in spring and autumn. The main community biomass, as a rule, was formed by diatoms, and in some years a significant proportion of the biomass was created by green algae. The dominant complex structure varied over time. In 2006-2007, the dominant species included green algae *B.lauterbornii*. In 2008 and prior to this year the prevailing species included *A.ehrenbergii*, *C.meneghiniana*, *Th.incerta*. The appearance of *C.jonesianus* as a dominant was recorded in 2009-2010, with increase of salinity level above 6% in the water

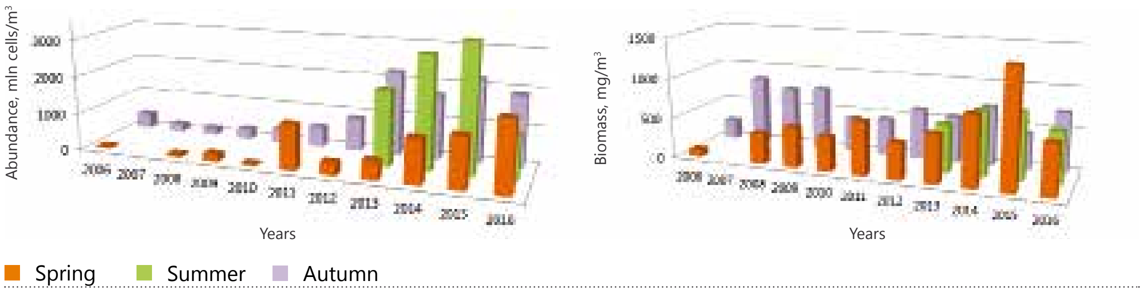


Figure 6.2.5 Seasonal and long-term dynamics of phytoplankton quantitative variable in Kashagan field

area under review. *C. jonesianus* dominated in the area under consideration up to 2015 inclusive. In 2011 and 2015, the dominants included diatom *C.clypeus*. In 2016, the phytoplankton biomass dominance had shifted to bottom species of diatom *N.sigma* and *D.ovalis*.

Similar to other parts in the water basin, the long-term dynamics of phytoplankton abundance and biomass in the Oil field pipeline area was characterized as a positive trend. Peak values of phytocenosis abundance and biomass in all seasons were recorded in 2016 (Figure 6.2.6).

A comparative analysis of the average annual values (determined for two seasons: spring and autumn) showed that the largest concentrations of unicellular algae were recorded in Aktote and Kairan areas (Figure 6.2.7). Phytoplankton abundance in other parts of the water body was lower. The main part of the total value was formed by blue-green algae (Figure 6.2.8). The maximum proportion of these species in the community abundance were recorded in Aktote and Kairan water areas.

Maximum values of phytoplankton biomass were recorded in the Oil field pipeline area (Figure 6.2.9). The phytoplankton communities in Aktote and Kairan areas had close values of this variable. The minimum values of plankton algae biomass were registered in Kalamkas and Kashagan area. The diatom algae were the main contributor into phytoplankton community's biomass at all locations (Figure 6.2.10).

The distribution of phytoplankton in the surveyed water area changed during the analyzed period (Figure 6.2.11). In 2006, the highest density of phytoplankton was recorded in the eastern part of Kashagan field.

In 2010, a significant decrease in the quantitative variable of phytoplankton was observed at certain stations of Kashagan field. The highest concentrations during this period were recorded in the deeper waters in the western part of Kalamkas. The algae biomass at this time was at its peak in the western part of Kashagan.

By 2016, quantitative variables of phytoplankton increased by several times as compared to the previous years. During this period the areas of algae mass development were located in shallower eastern parts of Aktote and along the Oil field pipeline route.

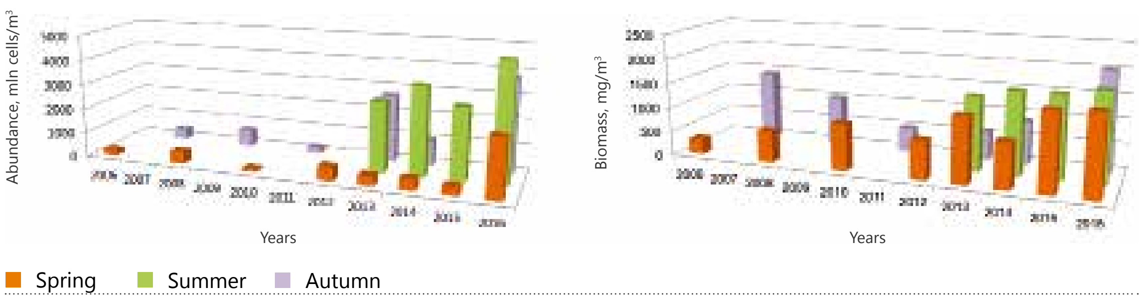


Figure 6.2.6 Seasonal and long-term dynamics of phytoplankton quantitative variable along the Oil field pipeline route

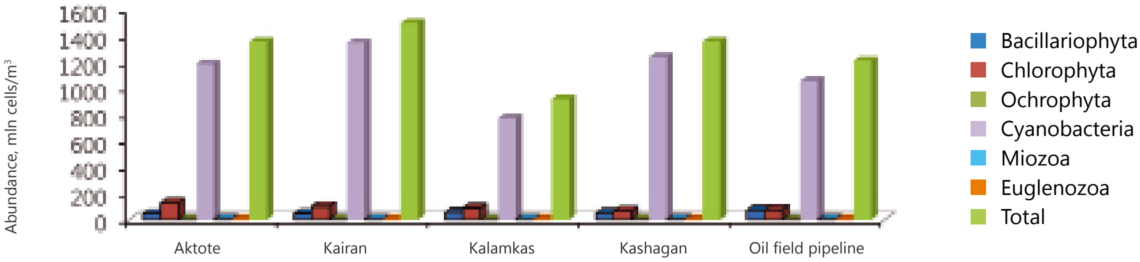


Figure 6.2.7 Comparative characteristics of the average annual values of phytoplankton abundance in the North-East Caspian Sea areas under survey

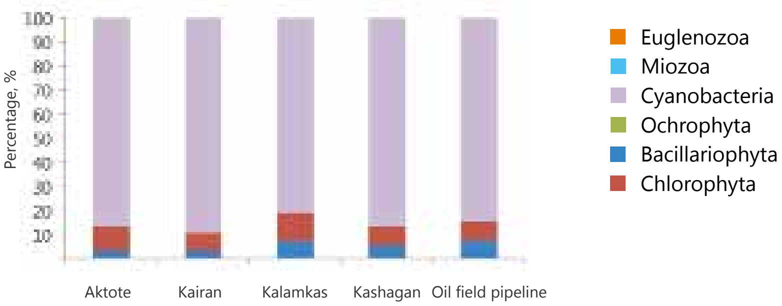


Figure 6.2.8 The proportion of groups in the total phytoplankton abundance in the North-East Caspian Sea areas under survey (average for spring, autumn)

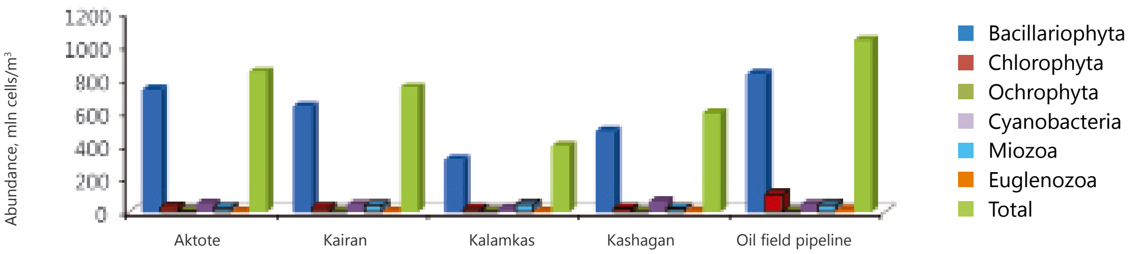


Figure 6.2.9 Comparative characteristics of the average annual values of the phytoplankton biomass in the Caspian Sea areas under survey

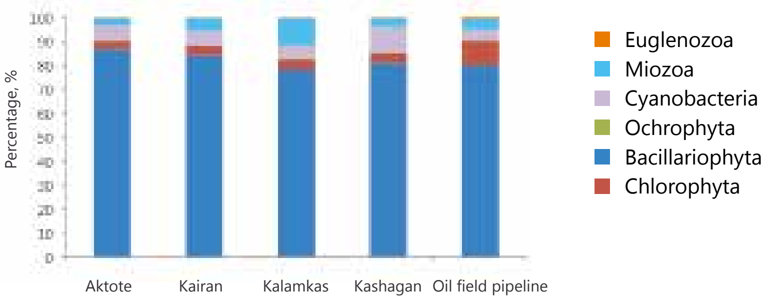


Figure 6.2.10. Proportion of groups in the total phytoplankton biomass in the North-East Caspian Sea areas under survey (average annual values)

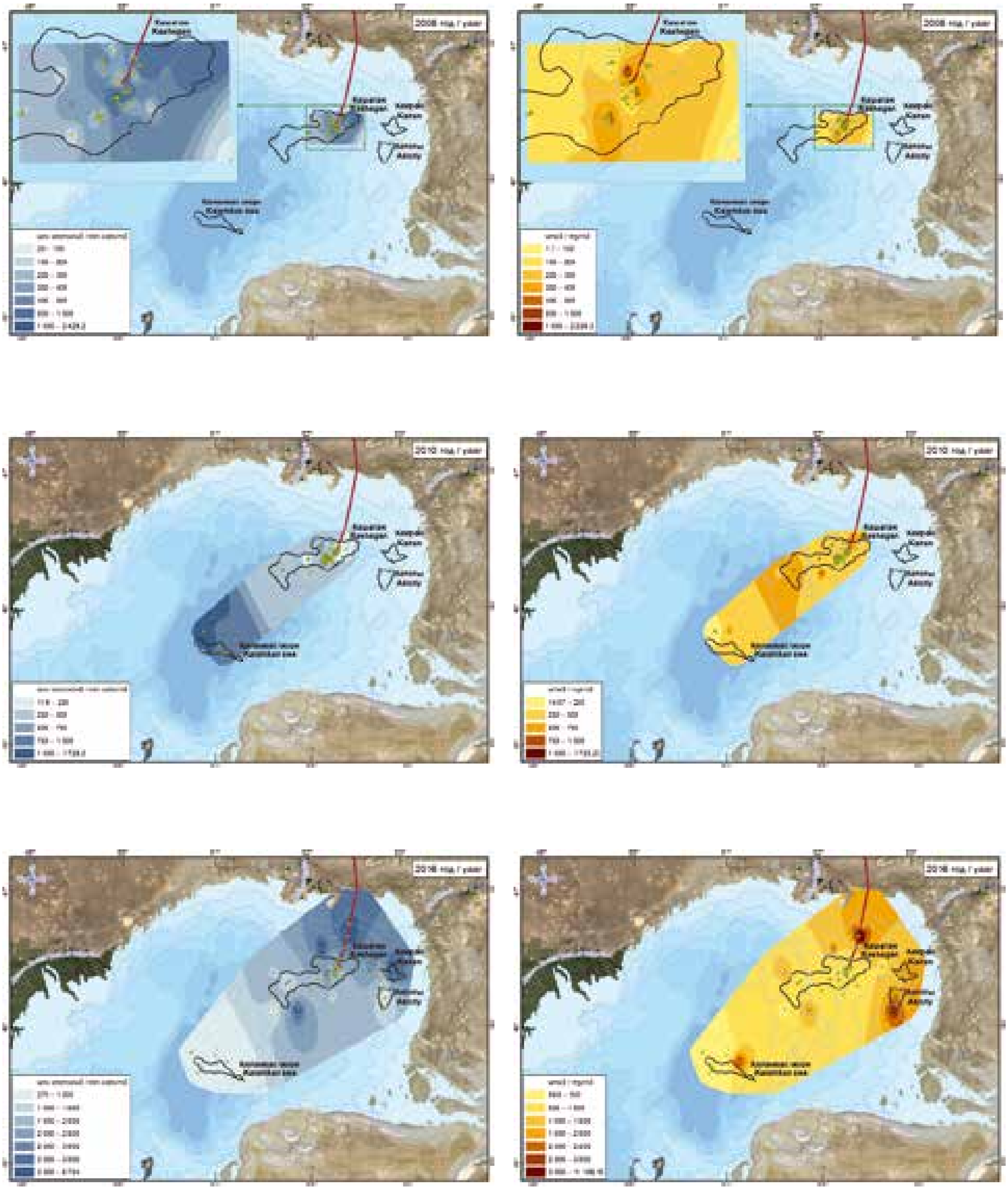


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Figure 6.2.11 Distribution of abundance (a) and biomass (b) of phytoplankton in the North-East Caspian Sea areas under survey in autumn periods

Impact of external factors on structural variables

The impact of external factors on the long-term dynamics of phytoplankton communities was researched. The data from the longest data sequence of autumn observations was used for the analysis.

The sea level drop during the last decade had been favorable for the species of the four plankton algae groups — diatom, green, blue-green and miozoa (Table 6.2-1). Correlation analysis showed that increase in the abundance of blue-green, diatom and green algae, as well as myozoa biomass along with the sea level drop, was statistically significant.

A negative statistically significant relation was also found between the abundance of diatom algae and concentrations of copper and mercury in water. Maximum copper concentrations were recorded in 2006, mercury — in 2008 (Chapter 4). In those years and up to 2010, the minimum values in diatom abundance were recorded. After 2010, there was an increase in abundance of diatoms due to reduction of concentrations of copper and mercury.

In 2008, the maximum values of vanadium, mercury, chromium and iron content were recorded in the water, and in 2009 — a higher content of ammonium. It had a negative impact on development of green algae. Correlation analysis showed a significant negative relation between the concentrations of vanadium, chromium, iron, mercury and quantitative variables of green algae. High concentrations of ammonium had a negative impact on both the abundance and biomass of green algae. From 2009, there has been a sharp decrease in the content of vanadium, mercury and chromium in water, after 2010 — ammonium and after 2011 — iron. With decrease in concentrations of these pollutants, the abundance and biomass of green algae increased.

Myozoa biomass increased after 2009 with decrease in the concentrations of copper and chromium.

Positive statistically significant relations were identified between the quantitative variables of ochrophyta algae and the content of barium, cadmium and iron in water. The abundance and biomass of this group species increased in the period of 2010-2015 with increase in concentrations of barium, cadmium and iron.

The higher water temperature had a positive impact only on the biomass of euglena algae.

Table 6.2-1 Correlation non-parametric analysis of the relation between quantitative variables of phytoplankton and environmental factors in autumn periods

Paired Variables	R	Paired Variables	R
Diatom Abundance - Level	-0.645	Ochrophyta Abundance - Cd	0,758
Diatom Abundance - Cu	-0,673	Ochrophyta Abundance - Fe	0,616
Diatom Abundance - Hg	-0,608	Blue-green Abundance - Transparency	-0,627
Green Biomass - NH4	-0,618	Blue-green Abundance - Level	-0,691
Green Biomass - Fe	-0,642	Blue-green Abundance - Vanadium	-0,817
Green Biomass - Hg	-0,725	Blue-green Abundance - Cr	-0,727
Green Abundance - NH4	-0,827	Blue-green Abundance - Hg	-0,636
Green Abundance - Level	-0,636	The average cell mass - NH4	0,609
Green Abundance - Vanadium	-0,688	The average cell mass - Vanadium	0,872
Green Abundance - Cr	-0,645	The average cell mass - Cr	0,609
Miozoa Biomass - Cu	-0,764	Phytoplankton Abundance - Transparency	-0,636
Miozoa Biomass - Level	-0,845	Phytoplankton Abundance - Level	-0,673
Miozoa Biomass - Cr	-0,673	Phytoplankton Abundance - Vanadium	-0,817
Ochrophyta Biomass - Ba	0,790	Phytoplankton Abundance - Cr	-0,691
Ochrophyta Biomass - Cd	0,758	Euglenozoa Biomass - Temperature	0,609
Ochrophyta Abundance - Ba	0,790		

Note: *R is the Spearman rank correlation coefficient, with* $p < 0.05$.

The abundance of blue-green algae increased under the conditions of lower water transparency and due to decrease in the content of vanadium, chromium and mercury after 2009. Given the leading role of blue-green algae, a similar relation was recorded between the total phytoplankton abundance and such factors as water level, transparency, vanadium and chromium content in the water. The average individual cell mass increased with increase of ammonium, vanadium and chromium concentrations in the water, mainly due to the suppression of small-celled blue-green and, to some extent, of green algae.

Conclusions

503 algae species have been identified in the phytoplankton composition. The abundance of plankton algae species varied over the years from 103 to 313. The most common were blue-*green Anathece clathrata*, *Lyngbya limnetica*, *Merismopedia minima*, *Merismopedia punctata*, diatoms *Cyclotella choctawhatcheeana*, *Cyclotella meneghiniana*, green algae *Binuclearia lauterbornii*.

The average annual value of phytoplankton abundance was 900.8 million cells/m^3, with biomass of 616 mg/m^3. The structural parameters of phytoplankton were quite similar in the water areas under survey in the North-East Caspian Sea. The core species in phytocenosis abundance at all locations were blue-green algae *(Cyanobacteria)* and the biomass was formed mainly with diatoms *(Bacillariophyta)*.

A trend in increase of phytoplankton quantitative variables had been revealed in the period from 2006 to 2016. The main contribution into the increase of phytoplankton abundance was made by blue-green, diatom and green algae, with diatoms contributed into the biomass growth.

During the period under study a change in the dominant biomass of the species complex had occurred. In 2006-2007, the following diatom species dominated: *C.meneghiniana*, *Actinocyclus ehrenbergii*, *Coscinodiscus lacustris*, green (*B.lauterbornii*) and blue-green (*Gomphosphaeriaaponia*, *Gomphosphaeria lacustris*) algae. In 2008-2010, domination of diatom *Coscinodiscus jonesianus* began in phytoplankton biomass. Since 2015, the role bottom diatom species (*Diploneis ovalis*, *A.ehrenbergii*, *Hyalodiscus sphaerophorus)* in phytoplankton had increased.

Phytoplankton structure depended on a number of natural and anthropogenic factors. The sea level drop was favorable for the main algae groups. Reduction of pollutant concentrations in the water had a positive impact on blue-green and, to some extent, on green algae.

7. ZOOPLANKTON

Material and Methods

In 2006–2007, zooplankton survey was carried out in autumn, in 2008–2012 – in spring and autumn, and in subsequent years in spring, summer and autumn [Reports, 2006–2016]. In total 2,596 zooplankton samples were taken and processed (Table 7-1).

At depths of more than 1 m, zooplankton samples were taken by double pulling a 12 cm diameter inlet Juday net from the bottom to the surface [Methodological Recommendations, 1984]. At lower depths, 100 litres of water were filtered through Apstein net. Plankton invertebrates were determined on the basis of indicators [Borutskii, 1952, Kutikova, 1964, Atlas of Invertebrates in the Caspian Sea, 1968, Fauna Indicator ..., 1969, Krupa et al., 2016, Rivier, 1998]. Quantitative variables of zooplankton were calculated using standard methods [Vinberg, 1950, Balushkina, Vinberg, 1979]. The longest sequence of data acquired in spring and autumn periods in 2008 – 2016 was used for a correct calculation of average annual abundance and biomass of zooplankton community. To characterise zooplankton structure Primer software was used to calculate the average number of taxa per sample and the Shannon diversity index (Shannon Ab – abundance, bit/specs, Shannon Bi – biomass, bit/mg). The average individual mass of specimen was calculated for each station by dividing the total number by the biomass value. Correlation and incremental data regression analyses were performed with Statistica software (at $p < 0.05$).

Table 7-1 Quantity of zooplankton samples taken

Variable	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Number of stations	74	73	197	143	247	188	180	389	409	428	268
Number of seasons	1	1	2	2	2	2	2	3	3	3	3

7.1 Species Richness

General characteristics

In total 119 taxa were identified in zooplankton, including rotifers – 49, Cladocerae – 23, copepods – 38, facultative plankters – 9 (Table 7.1-1). The number of plankton invertebrates varied by years between 36 and 79 and statistically depended on the number of seasons and stations covered by observations ($R = 0.713$, $p < 0.05$).

The most constant components of the plankton community were the rotifer *Brachionus quadridentatus*, copepods *Halicyclops sarsi, Acartia tonsa and Calanipeda aquae-dulcis,* barnacle crustaceans' larvae *Cirripedia* and bivalve molluscs *Bivalvia* (Table 1 Annex 5). In some seasons, the rotifers *Asplanchna priodonta, Brachionus plicatilis, Filinia longiseta, Keratella tropica and Synchaeta stylata,* cladoceran crustaceans *Podonevadne camptonyx* and *Podonevadne trigona*, the copepod *Heterocope caspia* and polychaete *Hediste diversicolor* were relatively common in the water area. All other plankton invertebrates were only found sporadically in limited water areas. Cladocerans ($R = 0.928$, $p < 0.05$) made the greatest contribution to the year-to-year variation of zooplankton species richness.

Spatial distribution

Zooplankton species richness varied in the water area under study two times. The largest number of plankton invertebrates was discovered in Kashagan field and Oil field pipeline water areas (Table 7.1-2). Zooplankton communities in Aktote area were less diverse in terms of species composition. A similar number of plankton invertebrates was registered in Kairan and Kalamkas water areas.

Year-to-year changes of the species richness of zooplankton communities in certain Contract Areas in statistical terms did not depend on the number of observation stations. Zooplankton species richness at Kashagan only slightly exceeded the number of plankton invertebrates recorded along the Oil field pipeline, while the

Table 7.1-1 Multiyear Dynamics of Zooplankton Species Richness in the Survey Water Areas of the North-East Caspian Sea

Year	Number of species				
	Rotifera	Cladocera	Copepoda	Others	Total
2006	11	3	17	5	36
2007	19	9	13	2	43
2008	21	10	21	7	59
2009	15	14	23	7	59
2010	16	7	25	8	56
2011	20	9	20	8	57
2012	19	10	20	8	57
2013	21	13	24	8	66
2014	32	19	21	7	79
2015	23	14	18	9	64
2016	20	11	22	8	61
Total	**49**	**23**	**38**	**9**	**119**

Table 7.1-2 Spatial Changes of Zooplankton Species Richness in the Water Areas under Study in the North-East Caspian Sea in 2006–2016

Water area	Rotifera	Cladocera	Copepoda	Others	Total	Number of stations
Aktote	19	13	13	18	57	127
Kairan	23	12	21	8	64	106
Kalamkas	25	12	21	9	67	324
Kashagan	43	21	40	9	113	1611
Oil field pipeline	39	23	37	8	107	209

number of stations varied up to eight times. Comparison of Kairan and Kalamkas data had a similar result. Analysis of the data for the entire observation period for each field allowed tracing a relation for certain groups only – cladocerans and others (R = 0.90., 0.97, Kalamkas and Kashagan), rotifers (R = 0.92, pipelines). It means that apart from the required and sufficient minimum number of observations to identify the maximum species richness of communities, another significant factor is the habitat diversity of the surveyed sites. The Oil field pipeline water area meets these conditions because it crosses zones of differing depths and salinity. It is evident that this factor contributed into comparable variables of species richness for Oil field pipeline and Kashagan zooplankton, with more homogenous hydrochemical and bathymetrical conditions given significant differences in the number of monitoring stations.

IN YEAR-TO-YEAR TERMS, SPECIES RICHNESS OF ZOOPLANKTON COMMUNITIES IN KAIRAN, KASHAGAN AND AKTOTE FIELDS AND OIL FIELD PIPELINE WATER AREAS CHANGED SYNCHRONICALLY (FIGURE 7.1.1).

Changes of zooplankton species number at the remote Kalamkas field were less synchronised with other Caspian water areas.

The most common species revealed in all survey years at all Contract Areas were the rotifers *Brachionus plicatilis and Keratella tropica*, the cladocerans *Podonevadne trigona*, the copepods *Acartia tonsa*, *Calanipeda aquae-dulcis* and *Halicyclops sarsi*, and *Bivalvia* and *Cirripedia* larvae. In terms of representation in plankton, they slightly lagged behind the rotifers *Asplanchna priodonta*, *Brachionus quadridentatus* and *Filinia longiseta*, the cladocera *Podonevadne camptonyx*, the copepods *Heterocope caspia* and polychaete larvae *Hediste diversicolor*. The *Synchaeta stylata*, *Trichocerca caspica*, *Brachionus angularis*, *Podonevadne angusta*, *Paraergasilus rylovi*, *Mesocyclops leuckarti*, *Laophonte mohammed*, *Limnocletodes behningi*, *Ectinosoma abrau*, *Blackfordia virginica* and *Rhithropanopeus harrisii* species, and the cercaria *Trematoda* were more widespread, although they showed a preference for certain water areas. Those that had adapted to specific zones were the rotifers *Notholca acuminata*, *Synchaeta vorax*, *Synchaeta cecilia*, *Brachionus calyciflorus* and *Brachionus urceus*, the cladocerae *Cornigerius maeoticus* and *Pleopis polyphemoides*, the harpacticoida *Ectinosoma concinnum and Nitocra typical*, and the hydrozoans *Moerisia maeotica* and *Moerisia pallasi*.

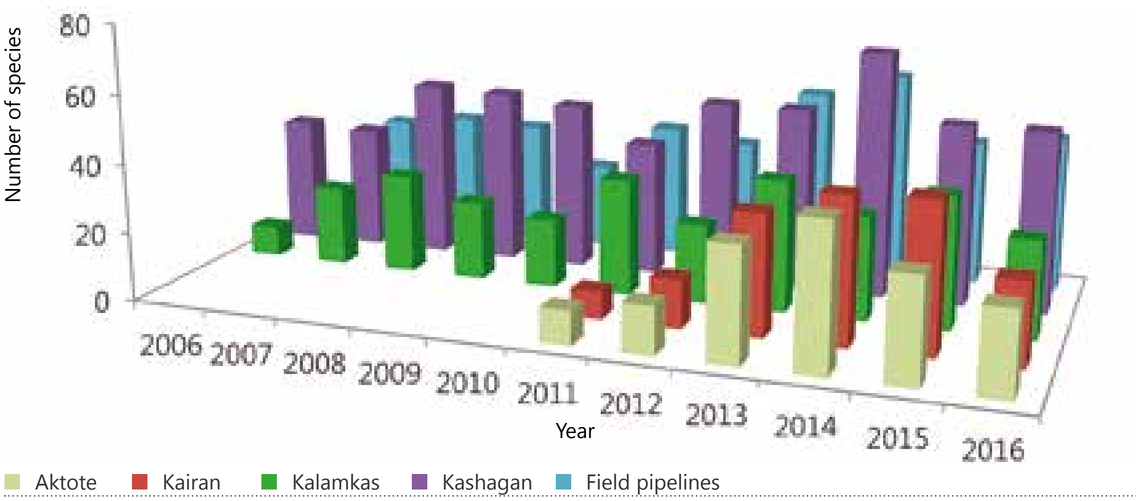


Figure 7.1.1 Long-term changes of zooplankton species richness in the surveyed water areas of the North-East Caspian Sea

7.2 Quantitative Variables

General characteristics

The average long-term abundance of zooplankton amounted to 25,941 specimens/m^3 (Annex 5, Table A2), with predominant copepods (66.6 % total). Rotifers (16.3 %) and facultative plankters (15.5 %) were found to be subdominant species. The average multiyear biomass reached 415.2 mg/m^3 (Annex 5, Table A3), predominantly made up of jellyfish – 68.8 % of the total. Excluding jellyfish, the biomass of plankton invertebrates themselves was 129.7 mg/m^3, with predominant copepods – 72.7 %. Cladocerans (11.8 %). Facultative inhabitants of the water column were found to be subdominant species (12.0 %).

Predominant species composition included more often copepods crustaceans *Acartia tonsa* and *Calanipeda aquae-dulcis*. In addition to these species, in certain water areas the rotifers *Brachionus angularis* and *Brachionus quadridentatus*, the cladocerans *Cornigerius maeoticus*, and the cyclops *Halicyclops sarsi* appeared to have the highest proportion in the total number of zooplankton. Even though the number was not high, meroplankton representatives such as large predatory jellyfish *Blackfordia virginica* and *Moerisia maeotica* dominated in biomass.

Due to significant impact of jellyfish on plankton invertebrates, we will review seasonal and annual changes of zooplankton abundance and biomass, inclusive and exclusive of jellyfish.

Seasonal and Long-term Changes of Zooplankton Quantitative Variables, Exclusive of Jellyfish

In 2013–2015, zooplankton abundance (Figure 7.2.1, a) and biomass (Figure 7.2.1, b) grew from spring to summer and fell by autumn, however, in 2016, the latest value in autumn was higher than in summer. More often, plankton invertebrates' abundance was higher in autumn than in spring. Year-to-year trends in changes of zooplankton abundance did not follow strict behaviour patterns. The highest spring zooplankton numbers were registered in 2011, 2012, 2014, and 2016. Maximum plankton community biomass values were recorded in 2009, 2011, and 2016. Over a four-year sequence of observations, summer zooplankton abundance and biomass changed in a dome mode. Autumn periods were characterised by irregular growth in the quantitative zooplankton variables between 2006 and 2016.

The analysis of average annual data (spring and autumn) showed trends in year-to-year increases of zooplankton abundance, predominantly by copepods (Figure 7.2.2, a). The year-to-year variability of zooplankton biomass depended on dynamics of copepods and, to a lesser extent, cladoceran crustaceans (Figure 7.2.2, b).

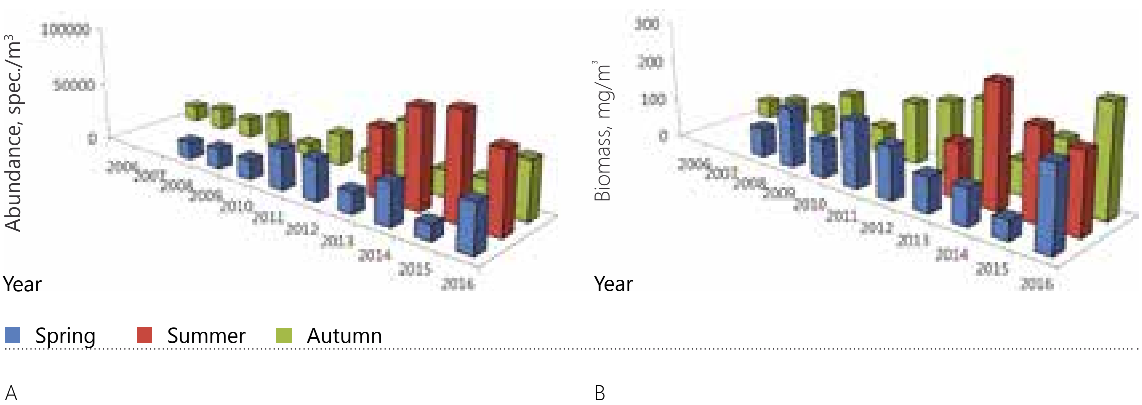


Figure 7.2.1 Seasonal and long-term changes of the zooplankton numbers (a) and biomass (b) in the surveyed water areas of the North-Caspian Sea (exclusive of jellyfish)

Seasonal and Long-term Changes in Quantitative Variables of Zooplankton, Inclusive of Jellyfish

Sporadic young jellyfish specimens *B. virginica*, *M. maeotica* and *M. pallasi* appeared in the water column at the end of spring. Due to the low numbers and small size of the specimens, jellyfish biomass in this period was very low (Figure 7.2.3, a). In 2013–2016, the total jellyfish biomass grew from spring to summer and by autumn fell again. In the autumn sequence of observations, the highest biomass of jellyfish was registered in 2008–2013. Figure 7.2.3, b indicates that jellyfish specimens had the greatest impact (85.7–99.5 %) on the year-to-year variability of zooplankton biomass. The averaged data for two seasons (spring and autumn) demonstrated a trend in jellyfish biomass reduction over the period under review.

Thus, the data analysis has shown that in the period 2008–2016, quantitative variables for plankton invertebrates grew, while jellyfish biomass, on the other hand, fell.

Spatial Distribution

In 2006–2010, surveys were not performed in Aktote field area. Zooplankton abundance in this particular water area in the period 2011–2016 amounted to 29,139 specimens/m³, with biomass at 162.3 mg/m³. Quantitative variables for zooplankton in spring reached on average 27,638 specimens/m³ and 104.5 mg/m³ and grew by summer to 167,151 specimens/m³ and 1,345.9 mg/m³ respectively (Figure 7.2.4). By autumn, these variables fell again to 30,946 specimens/m³ and 216.0 mg/m³. No specific trends in year-to-year changes of zooplankton were revealed in this area.

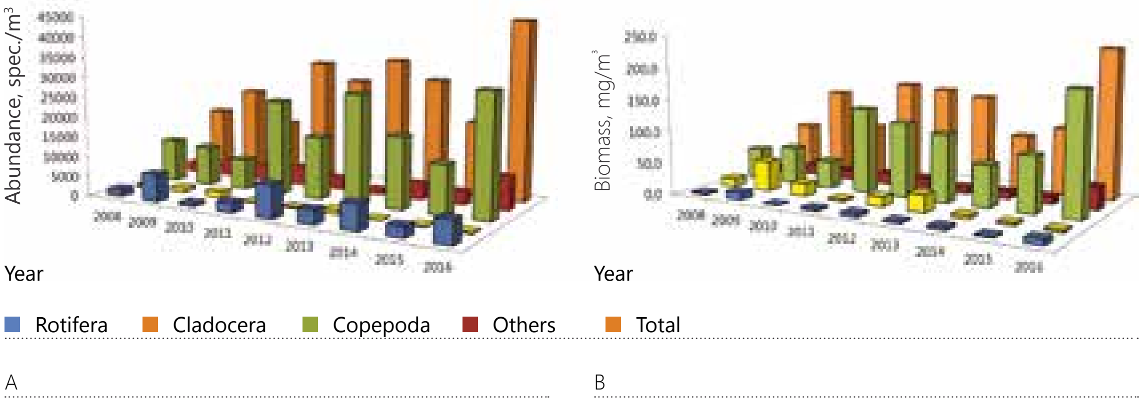


Figure 7.2.2 Long-term changes in the abundance (a) and biomass (b) of the main zooplankton groups in the surveyed water areas of the North-Caspian Sea (exclusive of jellyfish)

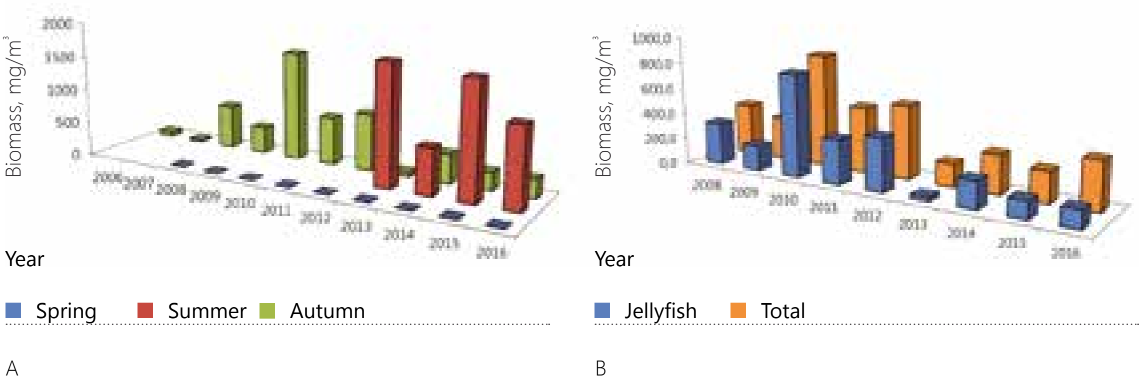


Figure 7.2.3 Seasonal and long-term changes in jellyfish biomass (a) and long-term changes in total zooplankton biomass (b) in the North-Caspian Sea (inclusive of jellyfish)

Zooplankton composition was characterized by dominating copepods crustaceans *Acartia tonsa and Calanipeda aquae-dulcis*, the rotifers *Brachionus angularis* and *Brachionus quadridentatus*. The jellyfish *Blackfordia virginica*, the copepods *Acartia tonsa* and *Calanipeda aquae-dulcis*, and the cladoceran *Cornigerius maeoticus* dominated in terms of biomass. The period under review saw a small rise with a subsequent fall in copepod crustaceans and rotifers abundance, and the mass development of hydroids in summer 2016.

In 2006–2010, no surveys were performed at Kairan field. Zooplankton abundance at Kairan field in 2011–2016 averaged to 36,840 specimens/m^3, with biomass of 196.4 mg/m^3. The quantitative variables of the plankton community increased on average from 40,180 specimens/m^3 and 143.0 mg/m^3 in spring to 85,022 specimens/m^3 and 848.7 mg/m^3 in summer respectively (Figure 7.2.5). By autumn, the abundance and biomass again fell to 46,214 specimens/m^3 and 306.2 mg/m^3 respectively. The zooplantkon abundance fell in spring and autumn during the analysed period.

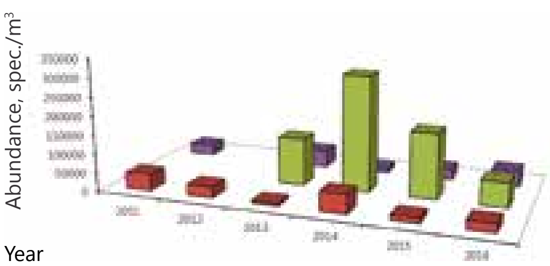
The predominant composite was represented by the copepod crustaceans *Acartia tonsa*, *Calanipeda aquae-dulcis* and *Halicyclops sarsi*, and the rotifer *Brachionus angularis*. The jellyfish *Blackfordia virginica*, the copepods *Acartia tonsa* and *Calanipeda aquae-dulcis* made the highest proportion in biomass.

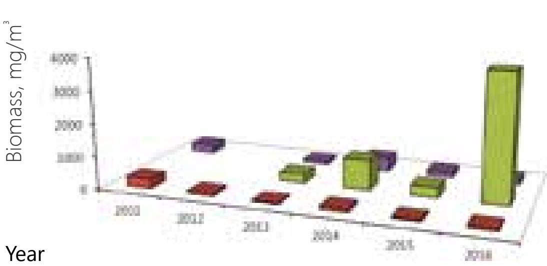
According to average long-term values (2008–2016), zooplankton abundance in Kalamkas field area equalled to 16,316 specimens/m^3, with biomass of 396.8 mg/m^3. The quantitative variables of zooplankton cenosis in spring reached on average 18,585 specimens/m^3 and 71.9 mg/m^3 (Figure 7.2.6). In summer, their abundance grew to 31,517 specimens/m^3 and 1,048.8 mg/m^3, while in autumn abundance fell again to 13,047 specimens/m^3 and 620.6 mg/m^3. In long term, there was a tendency of increase in quantitative variables of zooplankton in autumn and decrease in summer.

The predominant composite included a set of species common for the Caspian Sea, such as the copepods crustaceans *Acartia tonsa* and *Calanipeda aquae-dulcis*, the rotifers *Brachionus plicatilis*, *Synchaeta stylata* and *Brachionus quadridentatus*, and bivalve mollusc larvae (Table 7.2-1). According to average values, abundance of all plankton invertebrates, except for the rotifer *Synchaeta stylata*, increased with different levels of intensity. *Acartia tonsa* abundance grew most noticeably, while synchaeta abundance decreased by two orders of magnitude.

Jellyfish dominated in terms of biomass (Table 7.2-2). The copepod *Acartia tonsa* had the higher proportion in total biomass. The proportion of the jellyfish *Blackfordia virginica* in the plankton community biomass in 2011–2016 was higher than that recorded in the previous survey period. The proportion of holoplankton representatives such as copepods and cladoceran crustaceans in zooplankton decreased.

The average long-term abundance of plankton invertebrates at Kashagan field amounted to





Spring Summer Autumn

A

B

Figure 7.2.4 Seasonal and long-term changes in zooplankton abundance (a) and biomass (b) at Aktote field

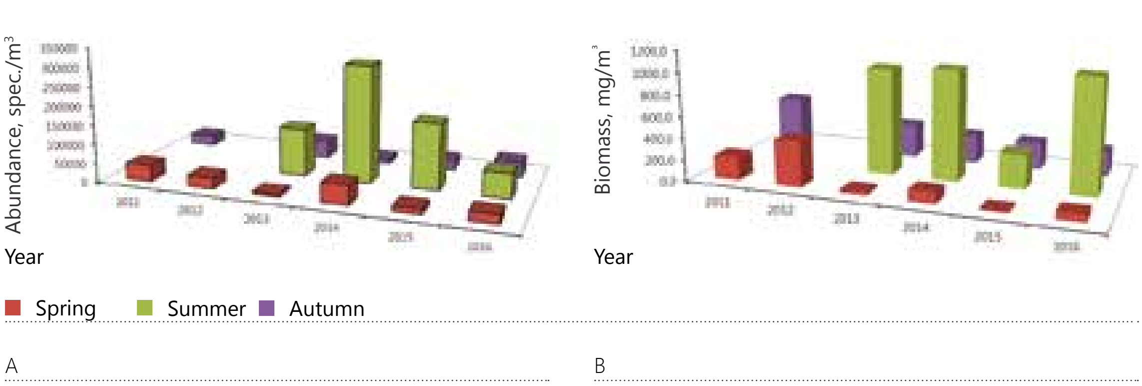


Figure 7.2.5 Seasonal and long-term changes of zooplankton abundance (a) and biomass (b) at Kairan field

26,695 specimens/m³, with biomass of 428.3 mg/m³. Maximum abundance of plankton community was seen in the summer period (Figure 7.2.7). The zooplankton quantitative variables grew on average from 24,110 specimens/m³ and 117.0 mg/m³ in spring to 61,650 specimens/m³ and 1,645.5 mg/m³ in summer respectively. By autumn, numbers and biomass again decreased to 26,842 specimens/m³ and 623.6 mg/m³. Zooplankton abundance tended to increase during all seasons. Zooplankton biomass had changed erratically on a year-to-year basis.

Copepods dominated, with a leading role played by *Acartia tonsa* and *Calanipeda aquae-dulcis* (Table 7.2-3). Barnacle crustaceans, bivalve molluscs, the cyclops *Halicyclops sarsi*, and the rotifers *Brachionus quadridentatus* and *Brachionus plicatilis* took a subdominant position in terms of abundance. In year-to-year term, all species abundance, except for barnacle crustaceans and cyclops, had grown with various intensity. The most noticeable was increase of *Acartia tonsa* abundance, i.e. almost four times higher.

Similar to other areas of the water basin, the zooplankton biomass was dominated by jellyfish *Blackfordia virginica* (Table 7.2-4). The copepods crustaceans *Acartia tonsa* and *Calanipeda aquae-dulcis* had approximately the same proportion in total biomass and were followed by the cladoceran *Podonevadne trigona* and the small jellyfish *Moerisia maeotica* and *Moerisia pallasi*. The long-term average values of biomass for all the above species, except for *Podonevadne trigona*, had increased.

According to average long-term values, zooplankton abundance along the Oil field pipeline route amounted to 36,749 specimens/m³,

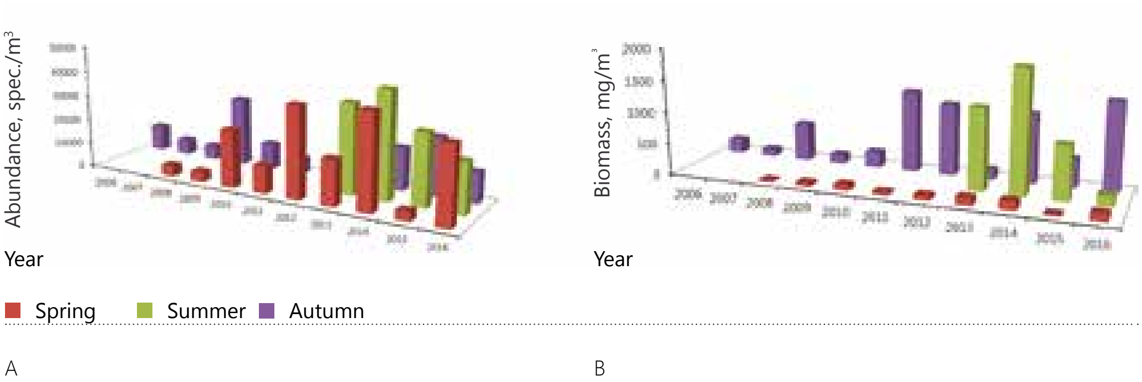


Figure 7.2.6 Seasonal and long-term changes of zooplankton abundance (a) and biomass (b) at Kalamkas field

Table 7.2-1 Average abundance and proportion of predominant species in total zooplankton abundance in Kalamkas field water area in 2006–2010 and in 2011–2016

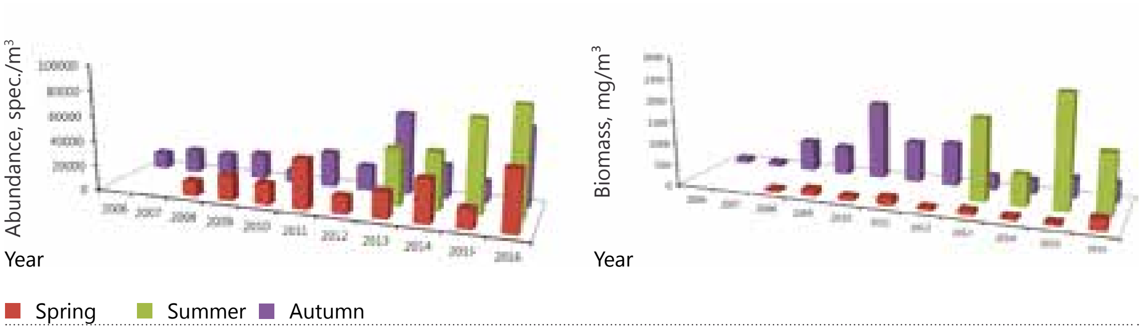
Taxon	2006-2010		2011-2016.	
	specimens/m³	%	specimens/m³	%
Acartia tonsa	5215	41.0	10952	49.0
Calanipeda aquae-dulcis	2562	20.1	3916	17.0
Brachionus quadridentatus	1504	11.8	1580	7.0
Synchaeta stylata	931	7.3	12	<1.0
Bivalvia gen sp.	708	5.6	2302	10.0
Brachionus plicatilis	23	0.2	1985	9.0

Figure 7.2.2 Long-term changes in the abundance (a) and biomass (b) of the main zooplankton groups in the surveyed water areas of the North-Caspian Sea (exclusive of jellyfish)

Taxon	2007-2010		2011-2016	
	mg/m³	%	mg/m³	%
Blackfordia virginica	117,4	65.4	537,1	84.5
Acartia tonsa	26,7	14.9	35,4	5.6
Calanipeda aquae-dulcis	12,9	7.2	23,4	3.7
Podonevadne trigona	8,3	4.6	2,7	0.4
Moerisia maeotica	0,0	0.0	13,7	2.2

with biomass of 286.4 mg/m³. The zooplankton quantitative variables reached on average 30,859 specimens/m³ and 109.7 mg/m³ in spring. The highest values of abundance and biomass of plankton communities were recorded in summer (Figure 7.2.8) averaging to 150,884 specimens/m³ and 2,005.1 mg/m³. In autumn, the values again fell to 40,745 specimens/m³ and 410.5 mg/m³. No regular changes were recorded in terms of year-to-year trends.

In terms of abundance, Copepods crustaceans dominated with a leading role of *Calanipeda aquae-dulcis*, *Acartia tonsa* and *Halicyclops sarsi* (Table 7.2-5). Rotifers sub-dominated, with a leading role of *Brachionus quadridentatus*,



A B

Figure 7.2.7 Seasonal and long-term changes of zooplankton abundance (a) and biomass (b) at Kashagan field

Table 7.2-3 Average abundance and proportion of predominant species in total zooplankton abundance at Kashagan field in 2006–2010 and in 2011–2016

Taxon	2006-2010		2011-2016.	
	specimens/m³	%	specimens/m³	%
Acartia tonsa	3550	24,3	14963	39,4
Calanipeda aquae-dulcis	3520	24,1	5073	13,4
Cirripedia gen.sp.	1914	13,1	1084	2,9
Bivalvia gen.sp.	1190	8,2	3374	8,9
Halicyclops sarsi	1050	7,2	579	1,5
Brachionus quadridentatus	1016	7.0	4811	12,7
Brachionus plicatilis	67	0,5	4238	11,2

Table 7.2-4 Average biomass and proportion of predominant species in total zooplankton biomass in Kashagan field water area in 2006–2010 and in 2011–2016

Taxon	2006-2010.		2011-2016	
	mg/m³	%	mg/m³	%
Blackfordia virginica	424,1	83,2	520,5	74,3
Calanipeda aquae-dulcis	18,6	3,6	39,5	5,6
Acartia tonsa	18,0	3,5	57,8	8,2
Podonevadne trigona	14,7	2,9	7,8	1,1
Moerisia maeotica	4,1	0,8	30,1	4,3
Moerisia pallasi	0,3	0,1	10,9	1,6

Brachionus angularis, *Asplanchna priodonta* and *Brachionus plicatilis*. In the last five years, the abundance of all mass forms, except for Asplanh, had grown. The most noticeable was the increase of *Acartia tonsa* abundance.

Before 2010, when hydrozoans were not recorded in zooplankton composition in this water area, the main contribution into zooplankton biomass was made by rotifer *Asplanchna priodonta*, the cladoceran *Podonevadne trigona*, and the copepods *Calanipeda aquae-dulcis* and *Acartia tonsa* (Table 7.2-6). In the subsequent period, jellyfish made the highest proportion of biomass, while the role of holoplankton species, fell accordingly.

A comparative analysis has shown that average annual zooplankton values almost double changed across all Contract Areas (Figure 7.2.9). The highest accumulations of plankton invertebrates were registered at Kairan and Aktote fields and along the Oil field pipeline route. The same distribution of zooplankton quantitative variables was recorded based on sampling analysis of 2006, 2010, and 2016 autumn data (Figure 7.2.10). Copepods crustaceans dominated everywhere (Figure 7.2.11). Rotifers and facultative inhabitants of water column were found to be subdominant species. The contribution of rotifers in generating the total zooplankton abundance was higher along the northern Oil field pipeline route.

The highest zooplankton biomass was recorded in Kalamkas and Kashagan water areas (Figure 7.2.12) due to predominance of large jellyfish. At these two sites, jellyfish zooplankton accounted for up to 80 % of the total mass (Figure 7.2.12, a). In all other zones, the proportion of jellyfish amounted to 10–30 % of community biomass.

Net of jellyfish, the ratio of the main groups in biomass terms was typical for the Caspian Sea. Copepods dominated across the entire water area (Figure 7.2.13, b). Cladocerae played an important role in generation of holoplankton biomass at Kalamkas and Kashagan fields and along the Oil field pipeline route. Zooplankton in the Oil field pipeline water areas was characterised by a relatively high proportion of rotifers in total biomass. The contribution of facultative plankters (exclusive of jellyfish) in total holoplankton biomass was almost similar to the entire water

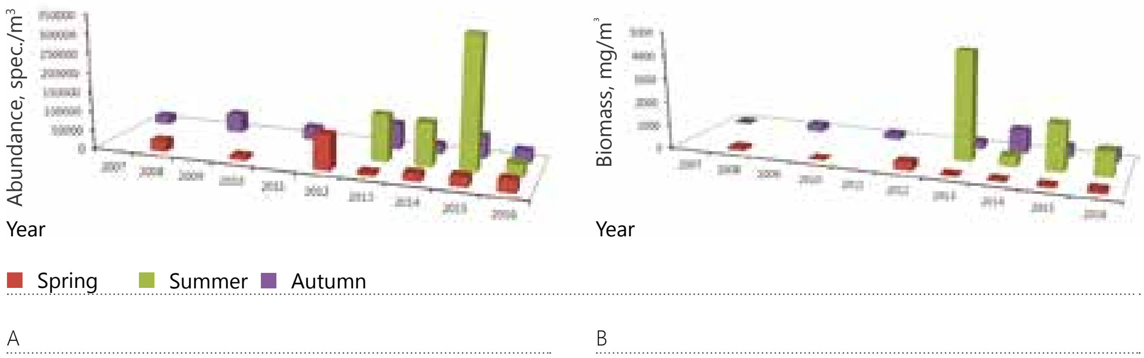


Figure 7.2.8 Seasonal and long-term changes in zooplankton abundance (a) and biomass (b) along the Oil field pipeline route

area under survey – 5.8–13.3 %.

7.3

Structural Variables

According to average seasonal values of Shannon index, zooplankton in the surveyed water area of the Caspian Sea is characterised by a low level of diversity (Table 7.3-1). Summer zooplankton (holoplankton, exclusive of jellyfish) was the most diverse in terms of the average number of species per sample and according to their distribution in terms of quantitative variables. Its structure in that season was characterised by the predominance of small species, which is confirmed by the average mass of the zooplankton. On numerous occasions we have registered a negative relation between Shannon diversity index values and size variables for plankton communities also for other water ecosystems in Kazakhstan [Krupa, 2012, Krupa et al., 2017, Krupa et al., 2018].

Similar holoplankton diversity values were registered in spring when jellyfish was not present. The appearance of jellyfish in the water column and its higher role in summer and autumn periods resulted in a linear increase of size variables from spring to summer and reduction of the Shannon diversity index values calculated for the proportion of species in total biomass (Shannon Bi, inclusive of jellyfish). Decrease in zooplankton diversity by autumn was also caused by partial or full elimination of cladoceran crustaceans. It was also related both to natural factors (the biological cycles of species and drops in the water temperature) and intensification of pressure from jellyfish plankton primarily eating away slow-moving cladoceran.

7.4

Impact of internal and external factors on zooplankton structural variables

Biotic interaction

Biotic interaction plays a significant role in regulation of seasonal and long-term changes in zooplankton communities. Caspian Sea holoplankton, apart from ichthyofauna stress, is impacted by meroplankton invertebrates – predator jellyfish such as *Blackfordia virginica*, *Moerisia pallasi* and *Moerisia maeotica* and the ctenophore *Mnemiopsis leidyi*. During the time sequence under review, ctenophore was only found locally (with frequency below 2 %) in 2010, 2012, and 2015 in sporadic cases, therefore, its impact on zooplankton can be disregarded.

The total average number of jellyfish reached 132 specimens/m^3 in summer, with biomass of 1,305.9 mg/m^3, in autumn – 26 specimens/m^3 and 474.9 mg/m^3. In spring 2008–2012, jellyfish appeared only sporadically with average abundance of less than 2 specimens/m^3. In spring 2013–2016, when the water temperature is lower, jelly species were not represented in zooplankton.

To analyse the impact of jellyfish on long-term

Table 7.2-5 Average abundance and proportion of predominant species in total zooplankton abundance in the Oil field pipeline area in 2006–2010 and in 2011–2016

Taxon	2006-2010.		2011-2016	
	specimens/m³	%	specimens/m³	%
Calanipeda aquae-dulcis	5841	23,5	7042	11,3
Brachionus quadridentatus	4189	16,9	8590	13,8
Acartia tonsa	3782	15,2	16935	27,1
Asplanchna priodonta	1754	7,1	760	1,2
Halicyclops sarsi	1409	5,7	1672	2,7
Brachionus angularis	340	1,4	7995	12,8
Brachionus plicatilis	626	2,5	6591	10,6

Table 7.2-6 Average biomass and proportion of predominant species in total zooplankton biomass in the Oil field pipeline area in 2006–2010 and in 2011–2016

Taxon	2006-2010		2011-2016	
	mg/m³	%	mg/m³	%
Asplanchna priodonta	50,6	27,0	6,9	0,8
Calanipeda aquae-dulcis	38,4	20,5	56,6	6,8
Acartia tonsa	27,0	14,4	90,7	10,9
Podonevadne trigona	13,6	7,3	2,8	0,3
Blackfordia virginica	0,0	0,0	497,6	59,8
Moerisia pallasi	0,0	0,0	72,1	8,7

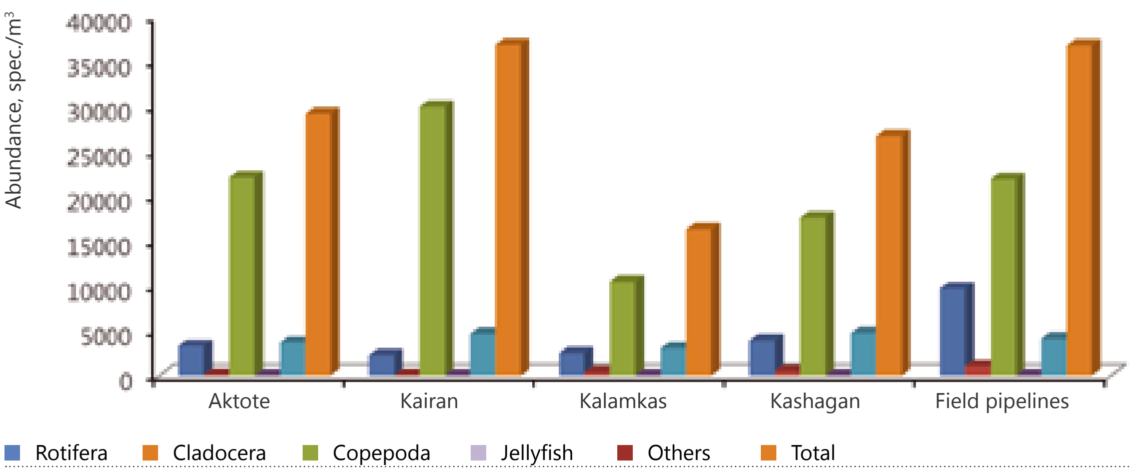
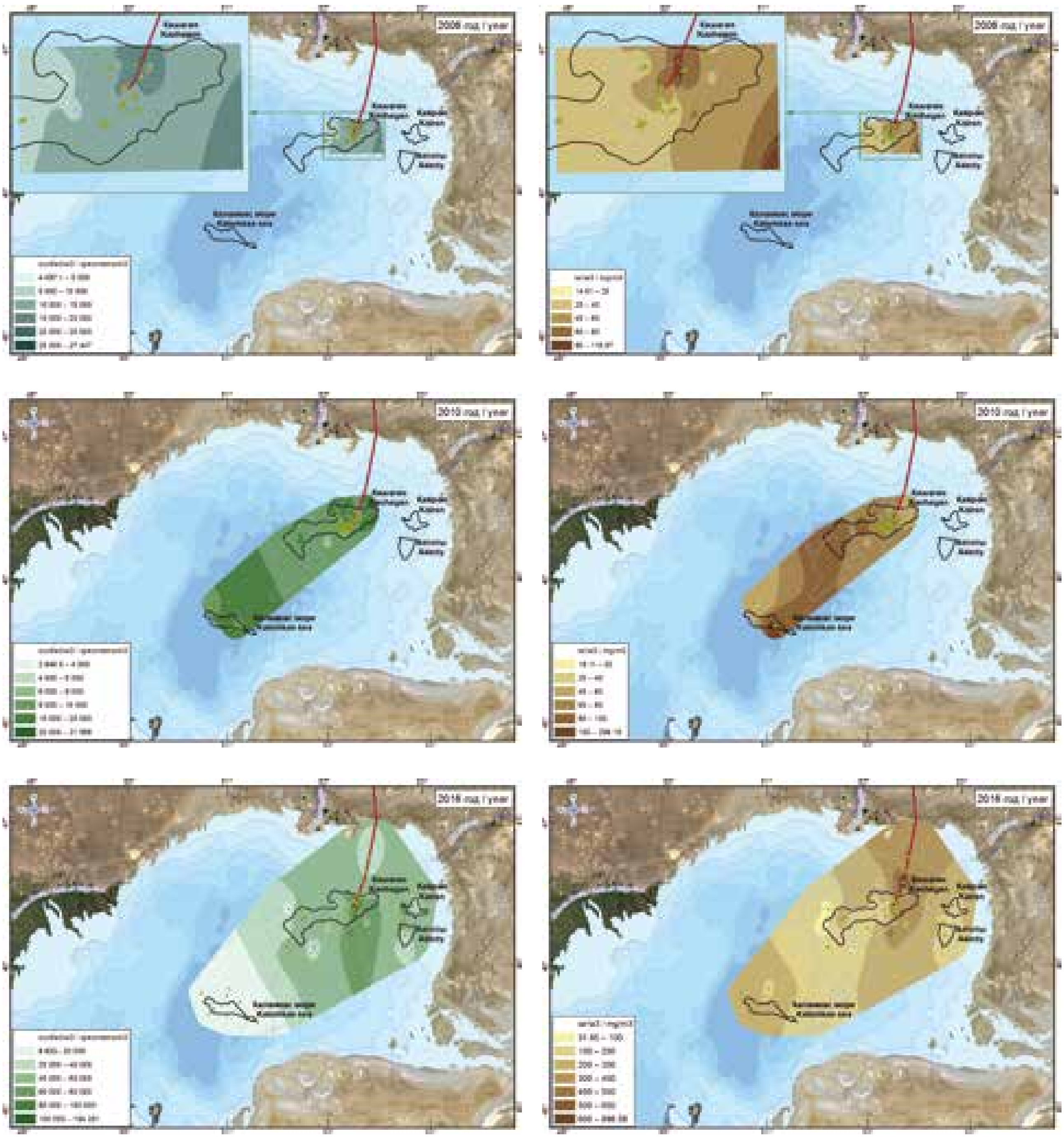


Figure 7.2.9 Spatial changes of zooplankton abundance in the surveyed water areas of the North-East Caspian Sea (average annual values)



A

B

Figure 7.2.10 Spatial changes of the holoplankton abundance and biomass in the surveyed water areas of the North-East Caspian Sea in autumn

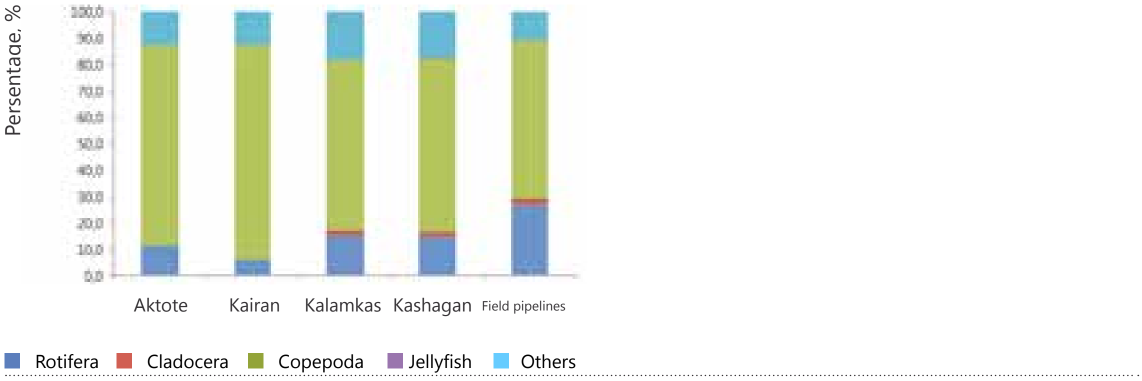


Figure 7.2.11 Change in proportion of the main groups in total zooplankton abundance in the surveyed water areas of the North Caspian Sea (average annual values)

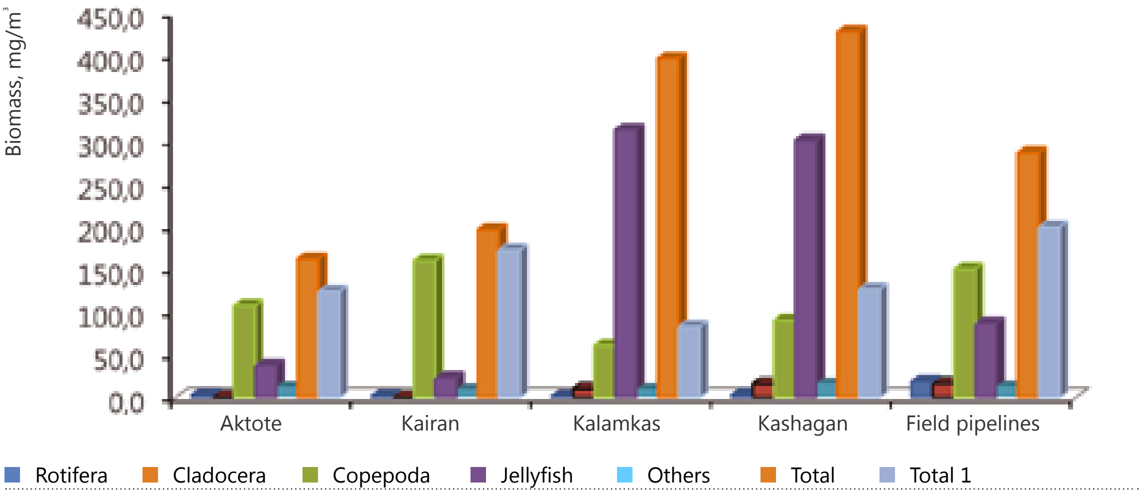
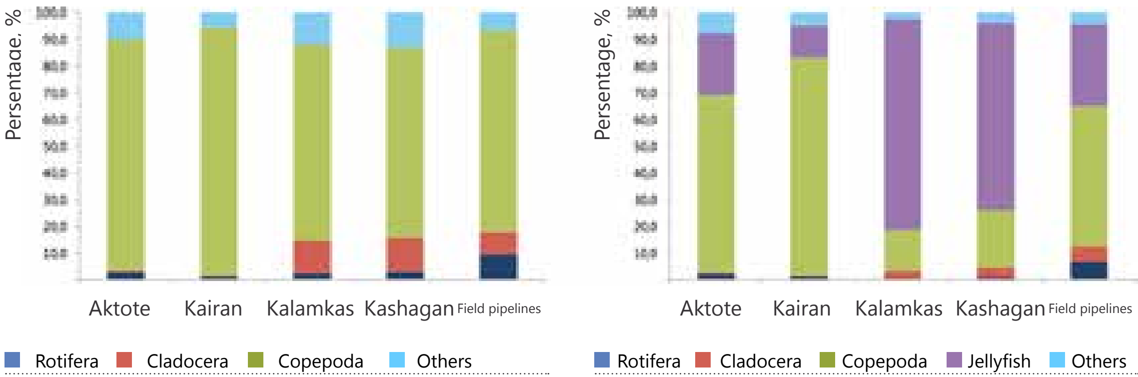


Figure 7.2.12 Spatial changes of zooplankton biomass in the surveyed water areas of the North-East Caspian Sea (average annual values)



a (total zooplankton)

b (exclusive of jellyfish)

Figure 7.2.13 Change in the proportion of the main groups in total zooplankton biomass in the surveyed water areas of the North-East Caspian Sea (average annual values) changes in the zooplankton structure the longest sequence of autumn monitoring data was used (2006–2016).

A correlation analysis showed that statistically the relation between the biomass of jellyfish and the main groups of plankton invertebrates was insignificant. One of the reasons is the short time sequence of data. However, data visualisation indicated that year-to-year variations of rotifer and cladoceran crustacean biomass was opposite to year-to-year changes in jellyfish biomass (Figure 7.4.1). The impact of jellyfish on long-term changes in copepods crustacean biomass and facultative inhabitants in the water columns was not traced. However, Figure 7.4.1 shows a positive trend in copepods changes as compared to year-to-year decrease in jellyfish biomass.

A spatial distribution analysis indicated that impact of jellyfish on holoplankton was not always traced. In summer 2013 and 2016, and autumn 2008, the relation between jellyfish and cladoceran crustaceans' biomass was statistically insignificant. In summer 2016, concentrations of jellyfish were registered predominantly in areas for concentration of rotifers and copepods. In autumn 2010, when the average biomass of jellyfish was the highest for the season (1,580.5 mg/m^3) in the time sequence under review, cladocerae were not present across the entire water area. In autumn 2006, jellyfish was found in approximately 33 % of the surveyed water area. Despite the small biomass of jellyfish in this period (on average 62.4 mg/m^3), the negative relation between the spatial distribution of cladoceran crustaceans and jellyfish was statistically significant ($R = -0.683$, $p < 0.05$).

A sampling analysis of biomass distribution maps for plankton invertebrates in autumn 2006, 2010 and 2016 showed that holoplankton and jellyfish accumulations were registered in various water basin areas (Figure 7.4.2).

The average individual mass of specimens is an integral characteristics of the structure of communities, because it reflects the ratio of all species and size groups in quantitative variables. The size is changing under impact of both internal (the biological cycles of community species, the influence of predators and others) and external factors (organic pollution, eutrophication and toxic pollution).

Analysis of multiyear dynamics in holoplankton structure size in the spring period showed that the average individual mass of specimens changed in opposition to total community abundance (Figure 7.4.3). The relation between size structure and biomass was poorly traced. It means that in spring at the beginning of vegetation season, zooplankton abundance grew because of smaller species or younger invertebrate plankton.

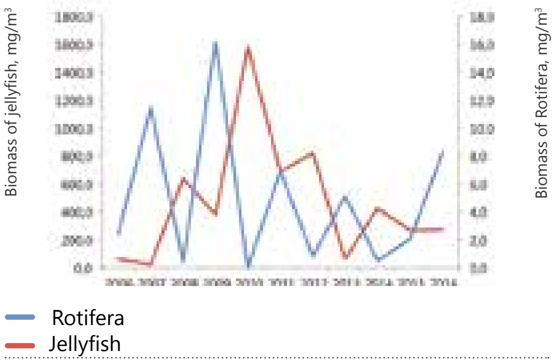
In summer, the biotic values under analysis changed in an opposite direction (Figure 7.4.4, a). Analysis of the diagram confirms that size structure was affected by predator jellyfish, which in the review season accounted for the highest biomass level. In autumn, no impact of jellyfish on zooplankton size was revealed (Figure 7.4.4, b). The established seasonal differences are caused by changes in the species composition of zooplankton communities. In summer, the main contribution to the increase in average individual specimen mass came from cladoceran crustaceans ($r = 0.947$), which are most commonly consumed by jellyfish zooplankton. In autumn, the size was determined predominantly by the proportion of facultative plankters (except for jellyfish) and copepods crustaceans, which are the most resistant to predators.

A non-linear drop in the average individual weight of zooplankter was observed in all seasons in the period 2006–2016 (Figures 7.4.3 and 7.4.4). Together with increase in long-term zooplankton quantitative parameters noted above (Figure 7.2.2), this may point to intensification of eutrophication processes in the

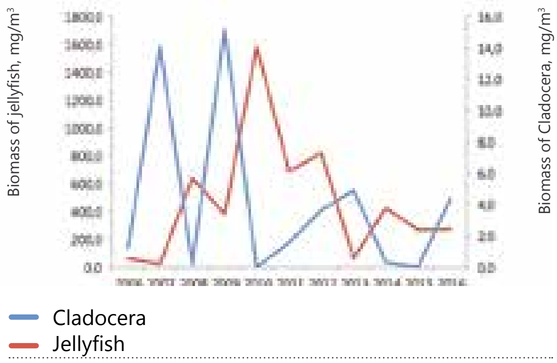
Table 7.3-1 Seasonal changes of zooplankton structural variables in the North-East Caspian Sea

Season	Number of species	Shannon diversity index			Average specimen mass	
		Ab, bit/specimen	Bi, bit/mg[1]	Bi, bit/mg[2]	mg/specimen[1]	mg/specimen[2]
Spring	10.8	2.10	1.97	1.97	0.0072	0.0072
Summer	13.6	2.15	1.41	2.15	0.0213	0.0028
Autumn	9.8	1.63	1.28	1.49	0.0353	0.0053

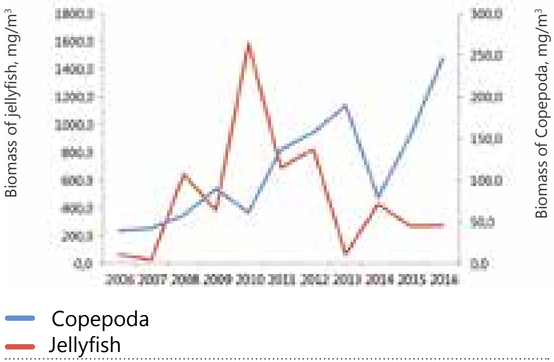
Note: *1 – value of variables inclusive of jellyfish, 2 – value of variables exclusive of jellyfish (holoplankton)*



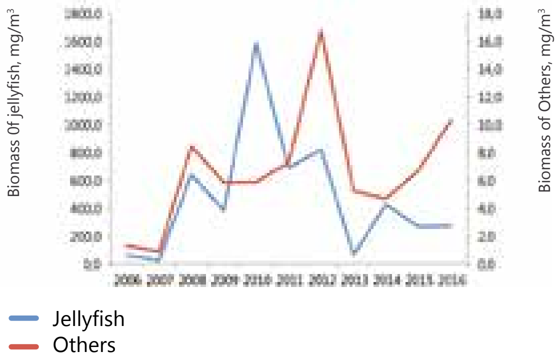
Rotifera



Cladocera



Copepoda



Others

Figure 7.4.1 Year-to-year changes in biomass of jellyfish and the main zooplankton groups in the North-East Caspian Sea in autumn

marine ecosystem.

Thus, cladoceran crustaceans and, to a less extent, rotifers, are the most vulnerable groups with respect to the impact of meroplankton predators. The change in abundance and size composition of jellyfish may be one of the reasons in year-to year changes in cladocera and rotifers. This is due to the lower mobility of cladoceran compared to copepods crustaceans. The most noticeable was the change in the structure of holoplankton due to jellyfish consuming cladoceran crustaceans in summer when the latter contributed into generation of the highest biomass. The impact of jellyfish on holoplankton was also traced during analysis of the size structure of communities. In autumn, when facultative plankters and copepods crustaceans dominated, the zooplankton community was even more resistant to impact of predators. Thus, the holoplankton structure in presence of jellyfish changes only under certain conditions, and it does not always show itself clearly.

Biotic interactions occur together with changes of external factors. Their significance is assessed below.

Impact of External Factors 7.5

An analysis was carried out to assess impact of 21 factors (sea level, depth, salinity and water transparency, ammonia, nitrate, common nitrogen, hydrocarbon, phenol, arsenic, barium, cadmium, chrome, lead, nickel, vanadium, and zinc content in the water) on year-to-year changes in zooplankton quantitative and size variables. The analysis was performed on the basis of autumn survey with the longest data sequences. In addition, an analysis was carried out to assess the impact of abiotic factors on the spatial distribution of plankton invertebrates in specific seasons and years.

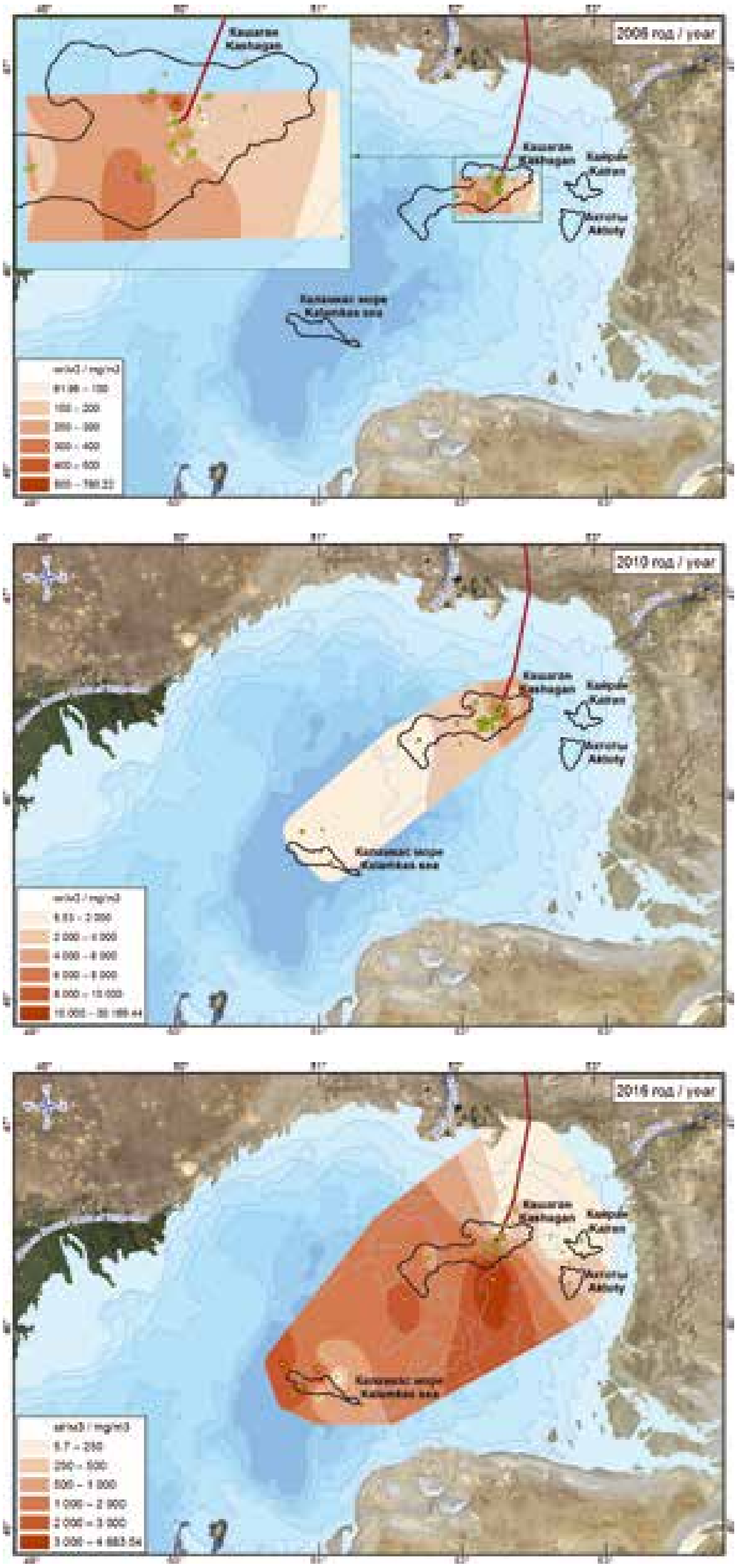


Figure 7.4.2

Distribution of total zooplankton biomass including jellyfish in surveyed locations of the North-East Caspian Sea water area in autumn periods

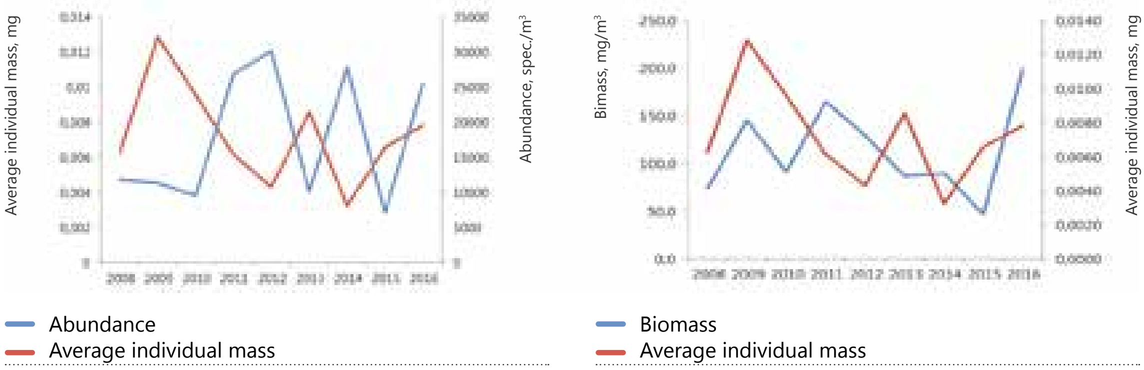


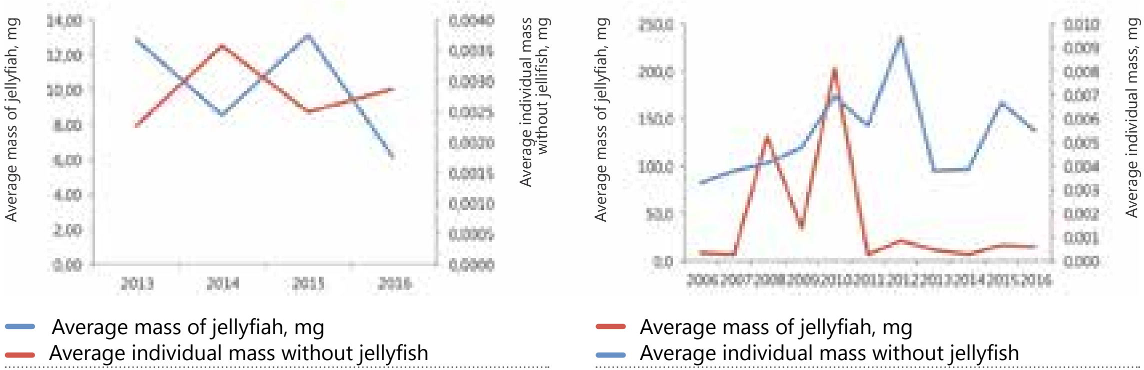
Figure 7.4.3 Long-term changes in size and quantitative variables for zooplankton communities in the North-East Caspian Sea in spring

The average long-term water temperature in spring reached 19.0 °C, in summer – 26.0 °C and in autumn – 14.2 °C. The highest temperatures were recorded in spring 2011 and autumn 2006. In summer months, the water temperature varied slightly between 25.2 and 26.8 °C. Over the long-term, the water temperature tended to fall in all seasons.

Hydrological conditions are one of the most important factors impacting the environmental state of aquatic ecosystems. Over the period under study (2006–2016), the sea level dropped linearly (Chapter 2, Figure 2.4). Out of the above listed factors, a statistically significant relation with the sea level was found only for four factors - average depth ($R = 0.609$, $p < 0.05$), water transparency ($R = 0.827$, $p < 0.05$), chrome ($R = 0.927$, $p < 0.05$) and copper ($R = 0.827$, $p < 0.05$) content in the water. A positive and very close relation between the sea level and concentrations of heavy metals can confirm that chrome and copper are brought to seawater predominantly together with river and surface water inflow, i.e. have an allochthonic origin.

Water salinity had a negative but statistically insignificant dependence on the sea level ($R = -0.427$). In spring, the highest water salinity was registered in 2011 and in autumn – in 2010 (Figure 7.5.1). In summer, the average water salinity was at its highest in 2015 and in 2016.

The correlation analysis indicates that hydrological conditions had the greatest impact on year-to-year changes in copepods crustaceans (Table 7.5-1). With the drop in the sea level and relevant changes in average water depth and transparency, copepods abundance and biomass grew. Chrome had an unfavourable impact on this group of aquatic invertebrates. Its year-to-year dynamics is also related to the water level. Given the dominant position of copepods crustaceans, similar relations were revealed between the above



A

B

Figure 7.4.4 Long-term dynamics of size variables for jellyfish and holoplankton in the North-East Caspian Sea in spring (a) and autumn (b) factors, as well as copper, and total zooplankton quantitative variables (exclusive of jellyfish). In addition to these factors, the total abundance of zooplankton increased under impact of nitrates. A positive and significant statistical relation was registered between copepod specimens and hydrocarbon content in the water.

A negative relation was revealed for rotifers with the arsenic content in water. Facultative plankton biomass had a positive dependence on nitrites. For cladoceran crustaceans, unfavourable conditions occurred with increase of water salinity. Water temperature and zinc had a positive impact on the species in this group. Holoplankton size variables increased with increase of water salinity level and nitrite content in the water.

No impact of hydrological conditions on jellyfish quantitative parameters was established. However, an indirect impact of this factor on jellyfish was traced through changes in environmental parameters – average depth and water salinity. Jellyfish biomass grew under higher salinity levels due to this group and the entire zooplankton community and also due to higher ammonia and nitrite concentrations in the water (Table 7.5-1). It is evident that higher biomass generated by jellyfish in autumn 2010 can be explained by hydrochemical conditions. Due to changes in water salinity, the summer jellyfish biomass changed reaching its minimum in 2014.

A multi-factor regressive incremental analysis showed that out of many factors water salinity (R^2 = −0.81, $p < 0.026$) is the most important for cladocerans. Hydrocarbon content in the water caused the main positive impact on the year-to-year dynamics of copepods (R^2 = 0.735, $p < 0.026$). For jellyfish, the most significant factor was the change in average depth (R^2= −0.70, $p < 0.026$). The nitrite content in water (R^2 = 0.810) had a positive impact on the average individual zooplankton mass.

Analysis of the *spatial distribution* of the main groups and total zooplankton in the area under study in the Caspian Sea in autumn 2008 and 2010 revealed only a weak relation with environmental factors. According to Spearman rank-order correlations, copepods crustaceans preferred shallow waters (R = −0.440) enriched with nitrites (R = 0.420), iron (R = 0.522) and mineral phosphorous (R = 0.480). Barium (R = −0.417), vanadium (R = −0.422) and common chrome (R = −0.443) had a negative impact on the "Others" group, while nickel (R = −0.415) had a similar impact on rotifers. The total zooplankton abundance and facultative plankters biomass was higher in 50 % cases in the areas with increased iron content in the water.

Thus, the copepod crustaceans and total zooplankton abundance grew against the linear fall of the sea level between 2006 and 2016. A negative relation between copepod quantitative variabless and chrome content in the water, correlated with the sea level, can reflect the indirect impact of hydrological parameters on this group of plankton invertebrates. It is evident that impact of hydrological conditions on jellyfish abundance was indirect and it occurred through changes in average water depth and salinity. For jellyfish, favourable conditions were generated with higher water salinity level, while cladoceran crustaceans showed the opposite preference. It is clear that under favourable conditions of higher salinity, jellyfish put more pressure on the cladoceran. Thus, the opposite trends in relation between jellyfish and cladoceran crustaceans and water salinity indirectly reflected a stronger pressure of predators on feeding zooplankton

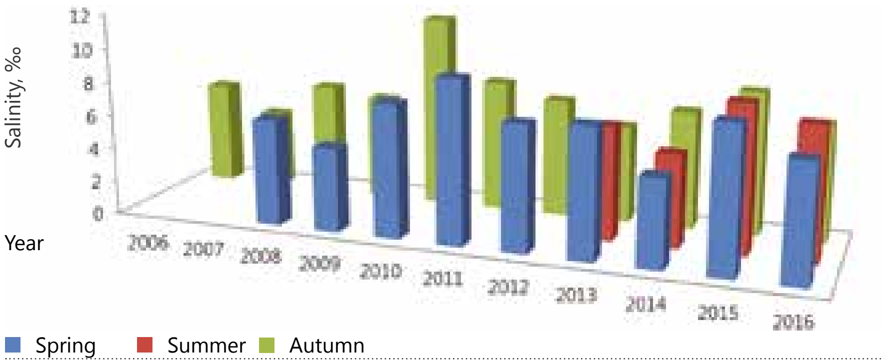


Figure 7.5.1 Year-to-year and seasonal changes in water salinity in the surveyed water area of the North-East Caspian Sea

Table 7.5-1 Correlation non-parametric analysis of the relation between zooplankton quantitative variables and environmental factors in autumn periods

Factor Pairs	R	Factor Pairs	R
Rotifera Abundance – arsenic	−0.673	Average individual weight of zooplankter – nitrites	0.642
Cladocera Abundance – salinity	−0.697	Jellyfish Abundance – depth	−0.736
Cladocera Biomass – salinity	−0.755	Jellyfish Biomass – salinity	0.709
Cladocera Abundance – zinc	0.685	Jellyfish Biomass – ammonium	0.636
Cladocera Biomass – zinc	0.655	Jellyfish Biomass – nitrites	0.752
Cladocera Biomass – temperature	0.636	Zooplankton Abundance – level	−0.645
Copepods Abundance – level	−0.773	Zooplankton Abundance – nitrates	0.691
Copepods Biomass – level	−0.845	Zooplankton biomass exclusive of jellyfish – level	−0.809
Copepods Abundance – transparency	−0.655	Zooplankton biomass exclusive of jellyfish – transparency	−0.800
Copepods Biomass – transparency	−0.818	Zooplankton biomass exclusive of jellyfish – chrome	−0.782
Copepods Abundance – depth	−0.636	Zooplankton biomass exclusive of jellyfish – copper	−0.655
Copepods Abundance – hydrocarbons	0.709	Zooplankton biomass with jellyfish – salinity	0.727
Copepods Biomass – hydrocarbons	0.609	Zooplankton biomass with jellyfish – nitrites	0.844
Copepods Biomass – chrome	−0.791	Biomass of others – nitirites	0.697
Average weight of zooplankter – salinity	0.800		

Note: *R is the Spearman rank-order correlation at* $p < 0.05$

under changing hydrochemical parameters, i.e. biotic interactions contributed to interim changes in hydrochemical parameters. The positive relation between water temperature and cladoceran crustaceans was caused by their representation among predominantly thermophilic species. A positive relation revealed between cladoceran crustaceans biomass and zinc content in water is of interest. Zinc is less toxic for cladoceran than other heavy metals [Braginskii et al., 1987], because it quickly excretes through exuviation [Muyssen, Janssen, 2002]. Previously, we had established a positive relation between cladoceran crustaceans' specimens and zinc concentrations in the Shardara water reservoir [Barinova, Krupa, 2018], which was caused by the spatial distribution of food zooplankton. Microalgae can accumulate in areas with higher zinc content, because low zinc concentration stimulates its reproduction [Cao et al., 2015]. It is evident that a positive relation revealed between year-to-year changes in cladoceran crustaceans and the zinc content in water is indirect and is explained by changes in trophic conditions.

Conclusions

In total 119 taxa were identified in zooplankton composition, including rotifers – 49, Cladocerae – 23, copepods – 38, facultative plankters – 9 in the area under study in the North-East Caspian Sea. The number of plankton invertebrates varied by years between 36 and 79. The most common species were the rotifers *Brachionus quadridentatus*, the copepods *Halicyclops sarsi*, *Acartia tonsa and Calanipeda aquae-dulcis*, the larvae of barnacle crustaceans *Cirripedia* and the bivalve molluscs *Bivalvia*.

The average long-term abundance of zooplankton amounted to 25,941 specimens/m^3 with biomass of 415.2 mg/m^3. Copepods dominated in terms of abundnce, with the highest proportion of jellyfish in biomass. Exclusive of jellyfish, holoplankton biomass amounted to 129.7 mg/m^3, with copepods having a leading role. The largest concentrations of plankton invertebrates were registered in Kairan and Aktote water areas and along the Oil field pipeline route. The highest zooplankton biomass was recorded in Kalamkas and Kashagan water areas due to the domination of jellyfish there. Zooplankton abundance was the highest in summer. In the period of 2008–2016, holoplankton quantitative variable increased while jellyfish biomass, on the contrary, decreased.

Predominant species included more often copepods crustaceans *Acartia tonsa* and *Calanipeda aquae-dulcis*. In addition to these species, in certain areas of the water basin - the rotifers *Brachionus angularis* and *Brachionus quadridentatus*, the cladoceran *Cornigerius maeoticus*, and the cyclops *Halicyclops sarsi*. In biomass terms jellyfish such as *Blackfordia virginica* and *Moerisia maeotica* dominated.

According to Shannon diversity index values (on average 1.63–2.15 bit/specimens and 1.49–2.15 bit/mg), zooplankton was characterised by its low diversity levels. Maximum community diversity was generated in summer by smaller species. The decrease of zooplankton diversity by autumn was caused by partial or full elimination of Cladocera from the community and the increase in pressure from jellyfish on holoplankton.

A non-linear year-to-year tendency in decrease of average value of individual zooplankters' mass was observed in all seasons. Given the year-to-year increase of zooplankton quantitative variables, it means intensification of eutrophication processes in the marine ecosystem against water level fall.

Analysis of biotic interactions showed that cladoceran crustaceans are under pressure of predator meroplankton. Changes in jellyfish abundance and size composition can be one of the reasons explaining the year-to-year changes in cladoceran and changes in holoplankton size variables in the summer period. The impact of jellyfish on year-to-year changes in biomass of copepods crustaceans and facultative inhabitants in the water column was not traced.

The impact of external factors on the structure of zooplankton communities was studied. Major part of environmental parameters did not have a statistically significant impact on year-to-year and spatial changes of plankton invertebrates. The impact of hydrological conditions and relevant environmental parameters (water depth, transparency, chrome and copper concentration) on copepods crustaceans and total holoplankton quantitative variables had been demonstrated. Higher salinity level was unfavourable for cladoceran crustaceans and stimulated development of jellyfish given changes in average water depths.

8. MACROZOOBENTHOS

Material and Research Methods

This chapter presents results of environmental monitoring in the North-East Caspian Sea at the Kashagan, Aktote and Kalamkas–sea ("Kalamkas") fields and along the Oil field pipeline route in the period of 2006–2016. [Monitoring Reports, 2006–2016].

In 2006 and 2008–2012, macrozoobenthos research was performed in spring and autumn (in 2007–in autumn only). During the period 2013–2016, it was performed in spring, summer and autumn.

Van Veen Grab Sampler (with grabbing capacity of 0.1 m2), Petersen Dredger (with grabbing capacity of 0.025 m2) and a tubular dredger (with grabbing capacity of 0.002 m2) were used to collect material. At each station, 2–3 benthos samples and in some years 5–10 benthos samples were collected and analysed. Samples were analysed in accordance with SRP 463–03 "Processing of Macrozoobenthos Samples" and Methodological Recommendations [Methods Guidelines ..., 1983, "Methodological...", 2006]. Identification tables were used to identify groups and species [Birstein, 1968, Morduchai-Boltovskii, 1969, Tsalolikhin, 1994, Alekseyev, 1995, Narchuk et al., 1997, Narchuk et al., 2000, Tsalolikhin, 2001 and Tsalolikhin, 2004].

The fullest data sequences (only spring and autumn studies) for 2006, and 2008–2016 were used to calculate long-term average and annual average abundance and biomass values. A correlation analysis was performed with Statistica software, while a cluster analysis and calculation of diversity indices were performed with Primer 6.0 software [Clarke..., 2001].

The scope of material is shown in Table 8–1

Table 8–1 Number of stations/number of samples of macrozoobenthos

	Number of stations/number of samples					
Years	Aktote	Kairan	Kalamkas	Kashagan	Oil field pipeline	Total
2006	16/32	16/32	1/2	252/504	28/56	313/626
2007	0	0	32/88	67/166	27/62	126/316
2008	0	0	54/270	324/1473	26/52	404/1795
2009	0	0	31/155	202/1010	19/57	252/1222
2010	0	0	46/138	317/951	24/72	387/1161
2011	32/96	32/96	40/120	243/729	27/81	374/1122
2012	18/54	17/51	6/18	297/891	15/45	353/1059
2013	97/291	90/270	84/252	780/2340	93/279	1144/3432
2014	108/324	89/267	66/198	777/2331	82/246	1122/3366
2015	99/297	84/252	64/192	843/2529	72/216	1162/3486
2016	51/153	42/126	42/126	501/1503	48/144	684/2052
Total	**421/1247**	**370/1094**	**466/1559**	**4603/14427**	**461/1310**	**6321/19637**

8.1 Species Composition

The species composition of the Caspian bottom fauna is significantly poorer than in the Azov–Black Sea basin and open-type seas. This is a consequence of a long isolation of the Caspian Sea from oceans, its lower salinity and low winter temperatures. In total 379 species of free–living bottom invertebrates are registered in the Caspian Sea, of which 90% fall into three main groups: crustaceans (143 species), molluscs (106 species) and worms (96 species); [Caspian…, 1985]. Approximately 240 species of bottom inhabitants are registered in the North Caspian Sea. [Caspian…, 1985; Kassymov, 1987]. The main benthos fauna groups are *Polychaeta, Crustacea (Amphipoda and Cumacea), Bivalvia* and *Gastropoda*, which have a high biomass, abundance and frequency of occurrence [Voinova et al., 2016].

According to the monitoring data acquired by NCOC N.V. in 1994–2006, 150 species of macrozoobenthos were recorded in the surveyed water bodies [Environmental monitoring., 2014].

During 2006–2016 research period, 175 taxa were found in the benthos composition, including *Vermes* (worms), which conditionally include *Nemertini, Plathelminthes, Nemathelminthes,* Annelida–17, *Mollusca* (molluscs)–25, *Crustacea* (crustaceans)–100, *Insecta* (insects)–23, others–10 (Annex 6, Table A1). Compared to the previous period (1994–2006), the fauna list includes additional 4 taxa that are new for this region. They are the Azov–Black Sea species *Gammarus* subtypicus; an inhabitant of the Volga water reservoirs *Stenogammarus (Wolgogammarus) dzjubani;* Atlantic mysids *Mesopodopsis slabberi;* and the Black Sea Tanaidacea *(Tanaidacea*, family *Tanaidae)*.

On average, the most widely distributed taxa in the monitoring period included the worms *Oligochaeta gen. sp,* Hediste diversi*color* and *Hypaniola kowalewskii*, the molluscs *Abra ovata*, and the crustaceans *Stenocuma graciloides* and *Pterocuma pectinata* (Annex 6, Table A1). All of them, except for *P.pectinata*, were permanent components of the benthos over the 11–year period. The species *P.pectinata* were relatively rare in 2006–2007, and then starting from 2008, became more common in the region. Some species, such as the polychaete *Manayunkia caspica* and mollusc *Hypanis angusticostata* (2006–2010), the molluscs Dreissena polymorpha and *Didacna trigonoiles* (2006–2007), the cumacean *Schizorhynchus scabriusculus* (2006–2009), and in some years–*Schizorhynchus bilamellatus*–were common only in certain years.

The abundance of registered macrozoobenthos species varied significantly over the years of studies, with peak values recorded in 2008, and the lowest values registered in 2007 (Table 8.1-1). The number of species depended more often on the number of stations, their spatial location and the monitoring seasons. As a rule, every year over

Table 8.1-1 Long-term changes in the species composition of macrozoobenthos in the surveyed water bodies of the North-East Caspian Sea, 2006–2016

Years	Vermes	Mollusca	Crustacea	Insecta	Others	Total
2006	7	10	52	3	3	75
2007	7	6	41	2	1	57
2008	12	12	72	10	5	111
2009	11	11	62	6	6	96
2010	8	11	56	3	5	83
2011	10	9	49	5	6	79
2012	10	8	45	2	6	71
2013	9	10	63	10	7	99
2014	9	6	56	7	5	83
2015	13	16	60	3	7	99
2016	11	16	58	6	5	96
Total for the entire period	**17**	**25**	**100**	**23**	**10**	**175**

Table 8.1-2 Distribution of species composition in the main macrozoobenthos groups at the surveyed water bodies of the North-East Caspian Sea, 2006–2016

Region	Number of species					
	Vermes	Mollusca	Crustacea	Insecta	Others	Total
Aktote	10	9	55	3	4	81
Kairan	9	10	53	5	5	82
Kalamkas	10	11	47	1	7	76
Kashagan	14	21	97	15	8	155
Oil field pipeline	14	14	63	16	5	112

70 species of macrozoobenthos were registered; out of them 60–72% included crustaceans. Decreased abundance of species in 2007 is explained by a single nature of observations (only in autumn and not 2–3 times a year as usually).

The spatial distribution of hydrobionts in the surveyed water areas was not uniform (Table 8.1-2). The highest abundance of species in benthos communities was found in Kashagan field area and along the Oil field pipeline routes. The lowest quantity of taxa was registered in Kalamkas field area. The most similar species richness and macrozoobenthos composition was found in Aktote and Kairan water bodies.

The difference in the number of observations is not always a determining factor in species richness. Thus, the total number of stations at Kashagan field is 13 times higher than along the Oil field pipeline routes, however, the difference in species abundance is not significant. This is due to extended length of the Oil field pipeline covering various biotopes. Predominance of crustaceans (56–67% of total species abundance) is common for the taxonomic structure in all Contract Areas, irrespective of their location.

8.2 Quantitative Variables

Average long-term values of macrozoobenthos abundance and biomass amounted to 7,877 specimens/m2 and 29,334 mg/m2, respectively. Two groups accounted for the major quantitative characteristics: worms for abundance (61%) and molluscs for biomass (68%).

Changes in average annual variables of benthos abundance in 2006–2016 period were more significant than biomass fluctuations (Annex 6, Tables A2 and A3). Average annual abundance was at its highest in 2006 and 2009, and at its lowest in 2011–2012. The highest values of average annual bottom sediment biomass were recorded in 2009–2010 and 2013, while the lowest biomass was registered in 2016.

In total, the dominance of a limited number of species is typical for the surveyed water areas. The worms *Oligochaeta gen.sp. H.diversicolor, M.caspica* and *H.kowalewskii* tended to dominate in abundance terms. The crustacean species *Corophium*, *Stenocuma* and *Stenogammarus*, and the mollusc *A.ovata* achieved mass development in a number of cases. In biomass terms, bivalve molluscs *A.ovata*, *Cerastoderma lamarcki*, *Didacna trigonoides* and *Hypanis angusticostata* and polychaete worms *H. diversicolor* dominated.

Thus, Oligochaeta gen.sp. and 7 species *(A.ovata*, *C.lamarcki*, *H.diversicolor*, *D.trigonoides*, *H.angusticostata*, *H.kowalewskii* and *M.caspica)* can be considered as baseline species for benthos communities in the surveyed water areas.

A.ovata (Abra segmenta) is an infauna representative that mines itself up to 5 cm in the soil, it is a detritus eater, Mediterranean euryhaline, inhabiting both in fresh waters and hypersaline water with salt content of in the range of 4-7 and 45% (optimum values of 9–11%). It prefers to settle in weakly compacted silty or silty-sandy soil and silty shells. It endures oxygen deficit well and is able to settle in areas with unstable oxygen conditions. Abra has been acclimatised in the Caspian Sea to increase the feed stock for benthos-feeding fish. These molluscs are the favourite food of sturgeon in the Asov basin. Abra acclimatisation has been attempted twice: in

1939 and in 1947–1948. The second attempt was successful, and by 1962 abra had spread across the entire Caspian Sea in all available depths with salinity ranging from 3% to 13%. At the same time, the highest concentration of molluscs (density of approximately 2,500 specimens/m^2 and above, biomass of up to 500 g/m2 and over) was recorded in salinity of 8-9% at depths of 6-12 m [Karpevich, 1975; Caspian..., 1985; Identifier..., 2013].

C.lamarcki is a mobile sestonophag that mines itself into the soil. The euryhaline species of Mediterranean–Atlantic origin is found in waters of 2.5-31% salinity. It prefers a soft sandy (with a light silt admixture), silty and sandy soil, silty with shell admixture soil and silty shell soil. It is resistant to temperature fluctuations and oxygen deficits [Nevesskaya, 1965; Grigorovich et al., 2003; Identifier..., 2013; Voinova et al., 2016].

H.diversicolor is a euryhaline species of Mediterranean–Atlantic origin that is found in water salinity of 2–13%. It was specially brought to the Caspian Sea in 1939–1941 to improve a feed stock for sturgeon. It is omnivorous. It is developing well in soft soil and in shallow water shells [Identifier..., 2015; Voinova et al., 2016].

D.trigonoides is an endemic Caspian species that is common in the North Caspian Sea at depths of approximately 5-10 m. Out of other Didacna species inhabiting mesa–saline water bodies (in the Caspian Sea-3-14%), only D.trigonoides enters oligohaline areas. It prefers a wide range of sea soil, from sandy and broken shells to mixed hard soil. It mines itself half way into the soil and it is a filtering organism [Identifier..., 2013].

H.angusticostata (Adacna polymorpha) is an endemic Caspian species that has a preference for silty sand, various types of silt with shells in the areas with weak current and favourable oxygen conditions. It is a filtering organism and sestonophag inhabiting in meso–saline water with salinity level in the range of 2-6% and 14% (optimum value of 5–10%, lethal level of 15%) [Identifier..., 2013].

H.kowalewskii is a Pontic-Caspian indigenous species that is found in silty soil in the waters with salinity range of 0-13%. It is a detritus eater [Identifier..., 2015; Voinova et al., 2016].

M.caspica is a Pontic-Caspian indigenous species that is found across the entire Caspian Sea in soft sea soil in the waters with salinity range of 2–13%. It is a detritus eater [Identifier..., 2015; Voinova et al., 2016].

NO CONSTANT TRENDS WERE ESTABLISHED FOR SEASONAL CHANGES IN MACROZOOBENTHOS QUANTITATIVE VARIABLES OVER THE 11–YEAR MONITORING PERIOD.

2009–2010 saw a drop in abundance from spring to autumn (Figure 8.2.1 a). In 2011–2015, the abundance remained stable during the year, without any evident seasonal fluctuations. 2016 saw a significant increase in abundance from spring to summer, followed by its multiple reduction by autumn to the level of spring values. Seasonal biomass changes in 2006, 2009, 2011, and 2013 were characterised by a small reduction from spring to autumn (Figure 8.2.1 b). In 2008, 2010, and 2014, biomass remained practically unchanged during the year. Biomass growth from spring to summer was recorded in 2012 and 2015. In 2016, benthos biomass and abundance reached its evident peak in summer.

The highest spring abundance levels were recorded in 2006 and 2008–2010. The maximum summer abundance was observed in 2016, while autumn abundance was the highest in 2006–2007 and 2009.

Changes in the average annual abundance and biomass of certain macrozoobenthos groups confirm their various contribution into total values and significant year–to–year variability (Figure 8.2.2; Annex 6, Tables A2 and A3).

Over the entire research period, changes in the total abundance were determined predominantly by fluctuations in the size of the *Vermes* group. This is confirmed by continuous reduction of its abundancy in the period 2006–2011, followed by its slow growth during 2012–2016 period (Figure 8.2.2 a).

Fluctuations in total biomass were of a wavelike nature with two peaks–in 2009 and 2013 (Figure 8.2.2 b). Changes in the *Mollusca* group, which accounts for the highest contribution into

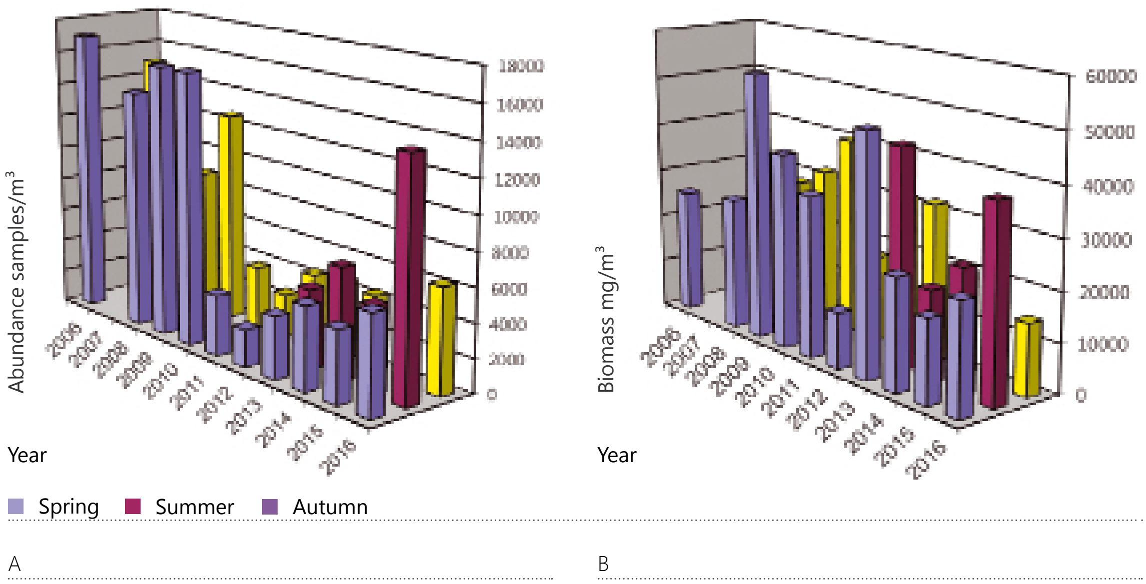


Figure 8.2.1 Long-term and seasonal changes in macrozoobenthos abundance (a) and biomass (b) in the surveyed water bodies of the North-East Caspian Sea, 2006–2016

formation of benthos biomass, confirmed exactly the observable year–to–year changes in total value.

The distribution of hydrobionts abundance and biomass across the water body is inhomogeneous. Average abundance of macrozoobenthos in various areas of the water body has changed over all years and seasons from 3,317 to 16,665 specimens/m2 (Table 8.2.1), with the highest value observed in 2006–2010 and maximum in 2009. Minimum values were recorded in 2011, while during 2012–2016 period, the abundance was relatively low. Average biomass changed in the range from 20,352 (2014) to 54,881 mg/m^2 (2009).

In 2006–2016, macrozoobenthos abundance changed from 0 to 152,500 specimens/m^2, biomass–from 0 to 678,780 mg/m^2 at all

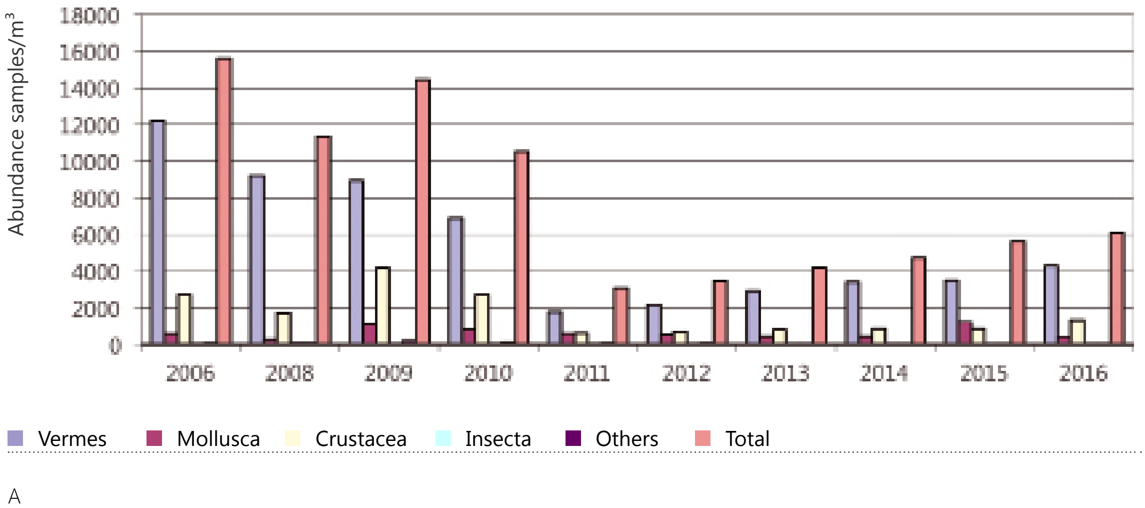
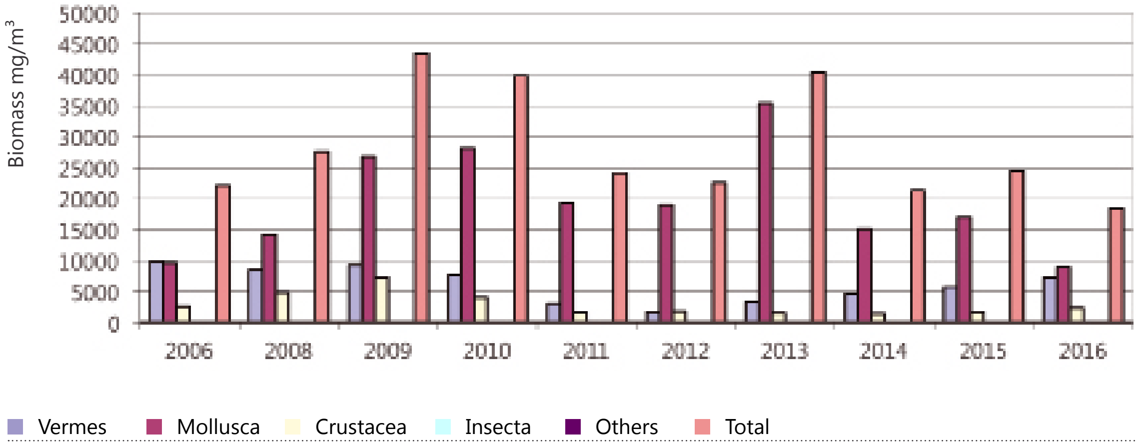


Figure 8.2.2 Change in average annual abundance (a) and biomass (b) of the main macrozoobenthos groups in 2006–2016



B

Figure 8.2.2 Change in average annual abundance (a) and biomass (b) of the main macrozoobenthos groups in 2006–2016

monitoring stations. The total absence of bottom species at some stations was noted four times: at two locations close to EPC3 island (Kashagan field) in autumn 2010 (EPC3–EB2) and in spring 2012 (EPC3–600/155), and in spring 2013–at the 3L/KRN–05 (Kairan field) and summer 2013-at the NP06–1000/W station (Oil field pipeline). Intensive construction works and operations and then drilling activities were carried out on EPC3 island in 2010. Assembling and commissioning works were performed in the area of Oil field pipeline route in 2013. No petroleum operations were conducted at Kairan field after 2007. Absence of aquatic organisms at the above stations was only recorded once. At all other times, benthos abundance was close to the average value for the water body.

The lowest average abundance in all areas under study for all years and seasons was seen in 2011, and the highest – in 2009. A dispersion analysis confirms a real impact ($p<0.05$) of the time factor (sampling year and season) on total abundance and the numbers of all main macrozoobenthos groups. In this respect, the year factor had a major impact. In season terms, macrozoobenthos abundance fell insignificantly from spring to autumn due to reduction of crustacean abundance. Mollusc abundance, on the contrary, increased by autumn. Worms abundance did not demonstrate any dependence on the season. Regarding average annual values, there is a general tendency in decrease of macrozoobenthos abundance. The total abundance decreased significantly in the period 2006–2011 (by 5 times), and then from autumn 2012, it began to grow again. The fluctuations in total abundance are related mainly to changes in worm abundance. In certain years (specifically, in 2009), crustaceans, such as p. Corophium made a significant contribution into total abundance. The major contribution in abundance development came from small oligochaetes *Oligochaeta gen.* sp. Before 2011, small indigenous polychaete such as *M.caspica* and *H.kowalewskii* were the subdominant species. In the period 2010–2011, the contribution of euryhaline invaders of polychaete worms *H.diversicolor* and bivalve molluscs *A.ovata* into generation of total abundance became higher. The polychaete *M.caspica* and *H.kowalewskii* are still found in the water basin under study, however, their abundance keeps reducing significantly.

The lowest average biomass by areas under study in all years and seasons was recorded in 2014, while the highest was recorded in 2009. A dispersion analysis confirms a real impact ($p<0.05$) of the time factor (sampling year and season) on the total biomass and the biomass of all main macrozoobenthos groups. The year factor has the most significant effect. The total benthos biomass depended mainly on changes in biomass of bivalve molluscs. In seasonal terms, the total macrozoobenthos biomass decreases by autumn due to reduction of mollusc biomass. In average annual terms, the total benthos biomass tends to decrease, mainly due to reduction of crustaceans' proportion, which made a significant contribution to creation of total biomass in 2008–2010.

Table 8.2–1 Structure of macrozoobenthos in the water areas under study in the North-East Caspian Sea in 2006–2016

Years	No. of species (Shannon Diversity Index)	Average abundance (min–max), specimens/m²	Average biomass (min–max), mg/m²	Dominant species	
				By abundance	By biomass
2006	75 (2,127)	15627 (400-77425)	22153 (150-144575)	*Oligochaeta gen.sp. (34%); Manayunkia caspica (26%); Hypaniola kowalewskii (13%)*	*Didacna trigonoides (27%); Oligochaeta gen.sp. (21%); Hediste diversicolor (20%)*
2007	57 (1,452)	12240 (140-152500)	23861 (16-169295)	*Oligochaeta gen.sp. (52%); Hypaniola kowalewskii (22%); Manayunkia caspica (17%)*	*Abra ovata (33%); Oligochaeta gen.sp. (18%); Didacna trigonoides (16%); Hediste diversicolor (15%); Rhithropanopeus harrisii (7%)*
2008	111 (2,369)	13478 (200-72380)	45392 (166-250492)	*Oligochaeta gen.sp. (31%); Manayunkia caspica (24%); Hypaniola kowalewskii (13%); p. Corophium (7%)*	*Didacna trigonoides (33%); Abra ovata (16%); Balanus improvisus (11%); Hediste diversicolor (9%); Oligochaeta gen.sp. (8%)*
2009	96 (2,828)	16665 (180-59930)	54881 (73-257109)	*Oligochaeta gen.sp. (22%); Manayunkia caspica (17%); p. Corophium (16%); Hypaniola kowalewskii (8%); Hediste diversicolor (7%)*	*Didacna trigonoides (20%); Hypanis angusticostata (17%); Abra ovata (17%); Balanus improvisus (15%); Hediste diversicolor (9%)*
2010	83 (2,489)	10975 (0-87290)	46148 (0-231264)	*Oligochaeta gen.sp. (24%); Manayunkia caspica (21%); p. Corophium (13%); Hypaniola kowalewskii (9%); Hediste diversicolor (8%); Abra ovata (7%)*	*Abra ovata (43%); Didacna trigonoides (16%); Hediste diversicolor (10%); Balanus improvisus (8%); Hypanis angusticostata (7%)*
2011	79 (2,449)	3317 (19-12720)	28077 (4,8-156777)	*Hediste diversicolor (25%); Abra ovata (18%); Oligochaeta gen.sp. (17%); Manayunkia caspica (8%); p. Corophium (7%)*	*Abra ovata (63%); Hediste diversicolor (10%); Didacna trigonoides (9%)*
2012	71 (2,185)	3479 (0-25660)	22568 (0-120172)	*Hediste diversicolor (26%); Oligochaeta gen.sp. (25%); Abra ovata (13%); p. Stenocuma (11%)*	*Abra ovata (49%); Cerastoderma lamarcki (29%)*
2013	99 (2,260)	4351 (0-36086)	41760 (0-678780)	*Oligochaeta gen.sp. (31%); Hediste diversicolor (13%); Abra ovata (13%); Hypaniola kowalewskii (12%); Manayunkia caspica (7%); p. Pterocuma (7%)*	*Abra ovata (62%); Cerastoderma lamarcki (23%)*
2014	83 (2,077)	5350 (7-56347)	20352 (0,7-214646)	*Oligochaeta gen.sp. (38%); Hypaniola kowalewskii (18%); Hediste diversicolor (12%); Abra ovata (8%)*	*Abra ovata (46%); Hediste diversicolor (14%); Cerastoderma lamarcki (12%); Didacna trigonoides (9%); Oligochaeta gen.sp. (7%)*
2015	99 (2,343)	5459 (67-56428)	24027 (80-256625)	*Oligochaeta gen.sp. (32%); Hediste diversicolor (18%); Abra ovata (12%); Hypaniola kowalewskii (7%)*	*Abra ovata (31%); Cerastoderma lamarcki; (27%) Hediste diversicolor (19%) Didacna trigonoides (8%)*
2016	96 (2,545)	8642 (27-150467)	25232 (13-374267)	*Oligochaeta gen.sp. (24%); Hediste diversicolor (20%); Hypaniola kowalewskii (14%)*	*Abra ovata (35%); Hediste diversicolor (26%); Cerastoderma lamarcki (11%); Didacna trigonoides (8%)*

The biomass of bivalve molluscs demonstrates cyclic fluctuations with peaks in 2009–2010 and in 2013. The role of the indigenous bivalve molluscs *D.trigonoides* and *H.angusticostata* in biomass has fallen, especially after 2010, however, the role of the euryhaline bivalve molluscs of Mediterranean–Atlantic origin *A.ovata* and *C.lamarcki* has grown.

Mosaic distribution of benthos is typical for the entire water body (Figure 8.2.3). This is particularly applicable to biomass predominantly created by molluscs in the majority of surveyed areas. In this respect, the places with increased benthos biomass tend to change in different years, which can be explained by population dynamics in macrobiotic bivalve molluscs. Year-to-year changes in the population abundance of macrobiotic species in natural conditions have a cyclic nature and often demonstrate various dynamics in local populations, which is typical for marine communities of bottom invertebrates [Gerassimova, 2001; Pogrebov and Kiiko, 2001].

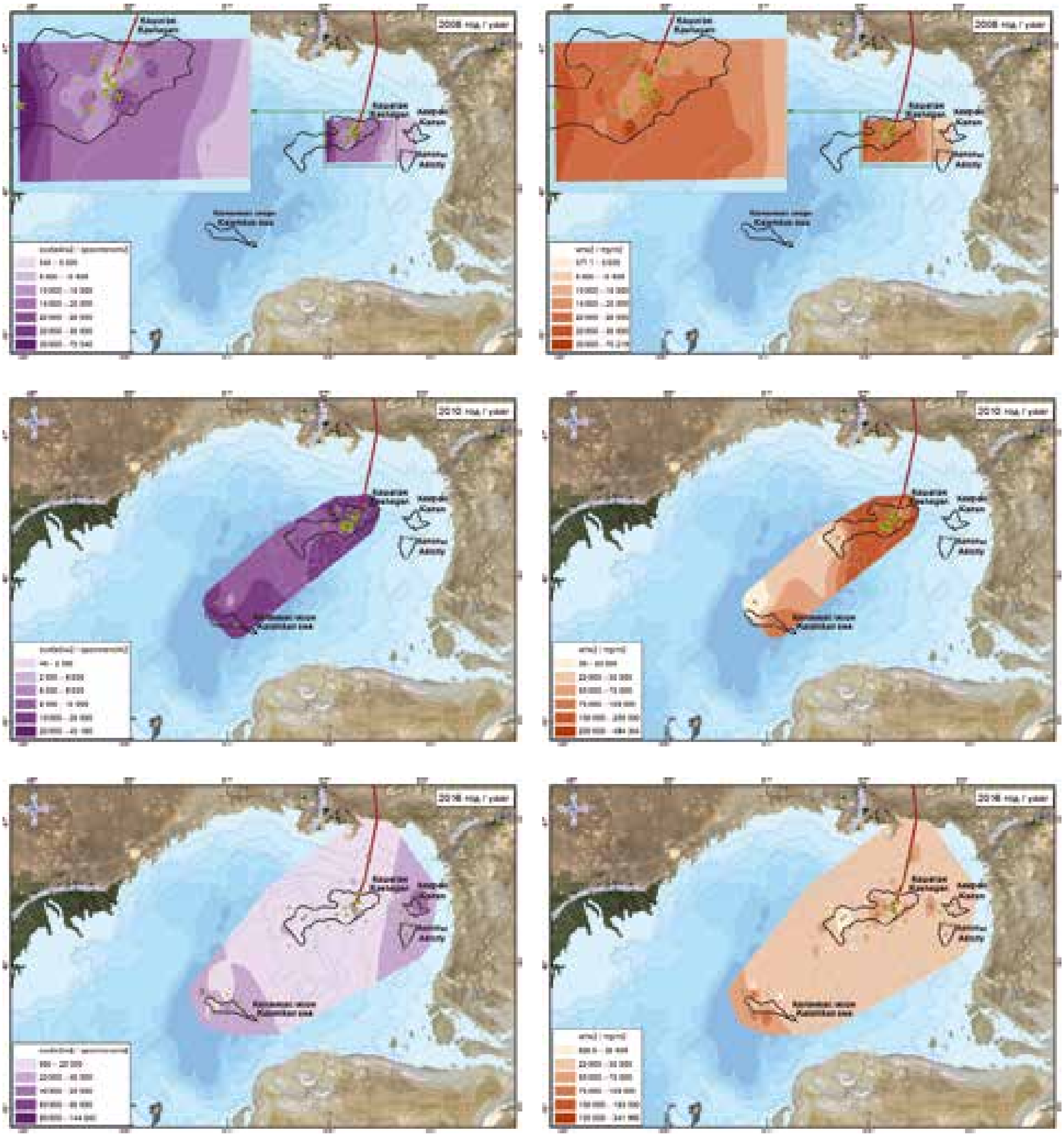
Analysis of benthos communities in major areas such as Kashagan, Kalamkas, Kairan and Aktote fields and Oil field pipeline and the cluster analysis performed both for species abundance and species biomass provides the best interpretable results (Figure 8.2.4). Though the dominant species are generally typical for the surveyed water body, the structure of bottom invertebrate community has some differences. According to the cluster analysis the most different in terms of bottom invertebrates' abundance is Kalamkas area (Figure 8.2.4 a). The highest abundance of benthos was recorded in this area. Besides, the proportion of the crustaceans *Corophium* and *Stenocuma* in its creating was significantly higher there than in other parts of the water body.

The cluster analysis performed on the basis of biomass of macrozoobenthos species shows that the most similar benthos communities were the following areas: 1-Kashagan and Kalamkas fields; 2–Kairan and Aktote fields and Oil field pipeline (Figure 8.2.4 b). The shallowest sections (Kairan and Aktote fields and Oil field pipeline) are different from the other water bodies both in terms of bottom sediments and hydrodynamic and hydrochemical characteristics. The quantitative variables of benthos in this area of the Caspian Sea are significantly low, while the role of worms *(Oligochaeta gen.sp. and H.diversicolor*) and crustaceans *(Balanus improvisus)* in creation of total biomass grew.

A statistical analysis (dispersion, correlation and cluster) showed a statistically significant dependence of the core parameters of bottom invertebrate communities on the observation year. A cluster analysis performed both for abundance and biomass of hydrobionts demonstrates a general split of the entire data into two clusters: the first cluster includes monitoring data for 2006–2010, while the second cluster includes monitoring data for 2011–2016 (Figure 8.2.5).

Thus, the benthos communities in the surveyed water bodies of the North-East Caspian Sea sustained significant changes in their structural characteristics in 2010–2011. After 2010, macrozoobenthos abundance had decreased by 3-5 times. This is mainly due to the reduction of small worm abundance, such as the oligochaetes and indigenous polychaete *M.caspica* and *H.kowalewskii,* which were dominant until 2011. 2011 saw a change in the dominant system, with growing role of invaders *H.diversicolor* and *A.ovata,* which inhabited the water body previously but were not dominant in abundance. In 2013, the oligochaetes and *H.kowalewskii* again became dominant; their abundance increased and returned to 2010 levels. *M.caspica* continues to be found in the surveyed water body, but it now accounts for 7% or less of total benthos abundance.

Changes in the total macrozoobenthos biomass were caused across the water body by fluctuations in the biomass of bivalve molluscs. In Kalamkas, Kairan and Aktote areas, the highest total benthos biomass in 2006–2016 always associated with the peak of *A.ovata* species development. At the same time, till 2010 biomass peaks in Kashagan area were caused by development of Caspian endemics *D.trigonoides* and *H.angusticostata*. Since 2010–2011, the dominant species in this area were the Mediterranean invaders, with the leading role transferring to *A.ovata* and with a subdominant role taken up by *C.lamarcki* or *H.diversicolor.*



A B

Figure 8.2.3 Distribution of macrozoobenthos abundance (a) and biomass (b) in the water body of the North-East Caspian Sea according to autumn observation data in 2006, 2010 and 2016

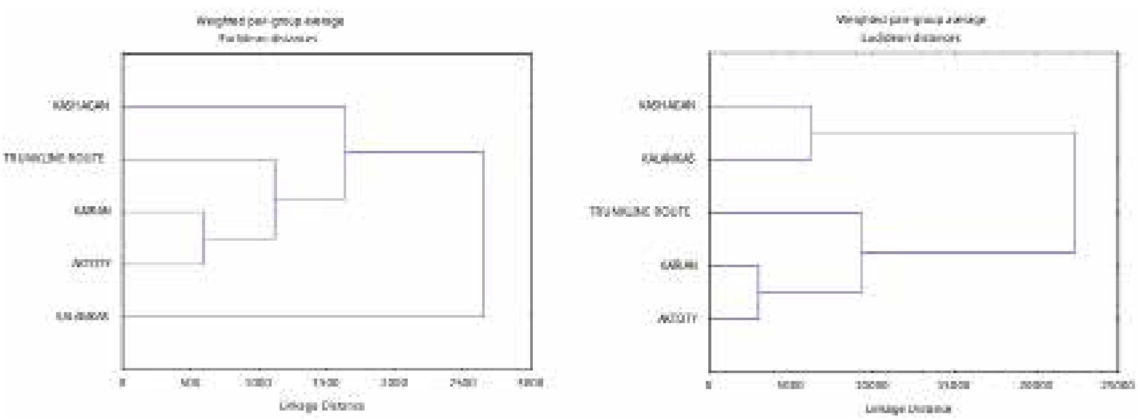
As mentioned above,

A SIMILAR CHANGE OF MOLLUSCS' DOMINANT SPECIES IN CERTAIN AREAS OF THE WATER BODY HAS USUALLY A CYCLIC NATURE AND CAN BE EXPLAINED BY THEIR NATURAL POPULATION DYNAMICS.

Changes in the hydrological and hydrochemical conditions in the Caspian Sea have also a cyclic nature and are generally determined by seasonal and year-to-year level fluctuations. In the course of its geological history, the level of the Caspian Sea has undergone several significant changes. Periodical rises and falls in sea levels are natural [Mikhailov et al., 1998; Hublaryan, 1995, 2000; Water..., 2016]. Sea level seasonal fluctuations (10–30 cm range) are typical for the Caspian Sea, with minimum values in winter and maximum in spring–summer seasons [Water..., 2016].

In recent years, the level of the Caspian Sea keeps falling. According to data from the Coordination Committee for Hydrometeorology and Monitoring of Pollution of the Caspian Sea (CCHMPCS) and Roshydromet, the sea level had dropped by nearly 1 m in the period of 2000–2016 [Coordination..., 2017]. The most significant drop was recorded in 2010–2011. According to the national hydro–meteorological organisations of the Pre–Caspian States, the second half of 2010 saw an abnormal seasonal drop in the level of the Caspian Sea, exceeding the average value by 1.5 times for the last 50 years. In the period from June to October 2010 the seasonal drop in the sea level, in the eastern part of the North Caspian Sea (Kulaly Island), was 44 cm. The reasons for such significant seasonal drop in the sea level included the unusually hot and dry summer in the Caspian region, and the low water level in the Volga River [Coordination..., 2010]. Thereafter, the level of the Caspian Sea also keeps falling. In 2016, the average level of the Caspian Sea was –27.99 m (Chapter 2, Figure 2.4) [Coordination..., 2017].

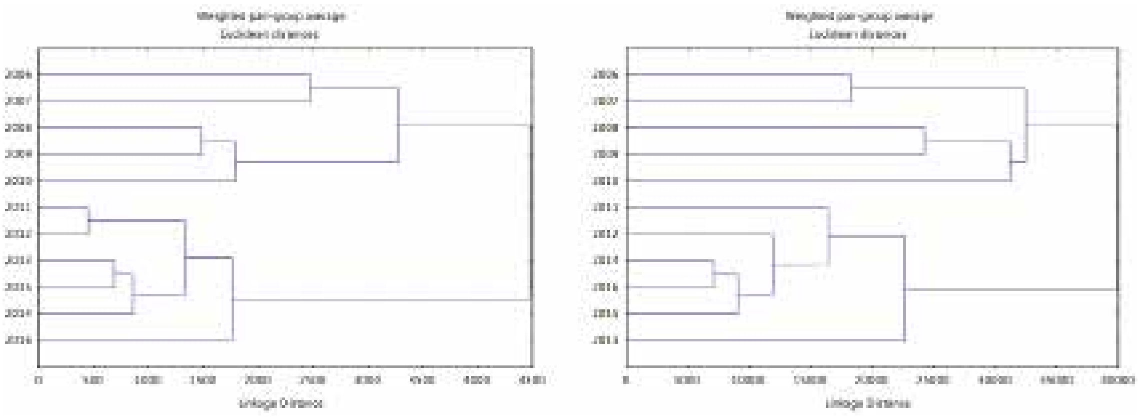
At the same time, changes in hydrological and hydrochemical conditions have also a significant impact on biological conditions in the Caspian Sea. Increase of the sea level is usually accompanied by desalination and increase in the concentration of biogenic elements brought by Volga water inflow [Katunin, 1992]. During periods when the North Caspian Sea level is high, it sustains intensive development of autochthonous species, with oligochaetes as the most developed in benthos. The same period saw a drop in abundance of Mediterranean bivalve molluscs–tserastoderms and arbi [Osadchikh et al., 1989]. According to multiyear monitoring data the mollusc *A.ovata* was practically non-existent in bottom communities of the North Caspian Sea in the period of the highest sea



A

B

Figure 8.2.4 Dendrogram of similarities in the surveyed areas for relative abundance (a) and relative biomass (b) of macrozoobenthos species



A B

Figure 8.2.5 Dendrogram of similarities between certain observation periods for relative abundance (a) and relative biomass (b) of macrozoobenthos species in the surveyed water body of the North-East Caspian Sea

level in the Caspian Sea in the period 1995–2007 (our days). In the same period, the areas of mass development of Polychaete *H.diversicolor* also diminished [Malinovskaya and Zinchenko, 2010], mainly due to desalination, which in some years reached 3.88% [Katunin et al., 2004].

In the period when the Caspian Sea level is at its lowest, which is usually accompanied by increased salinity, the opposite changes are noticed in macrozoobenthos, i.e. abundance of oligochaetes and small indigenous species of polychaete decreases, against the increase of the role of Mediterranean bivalve molluscs. A similar fact was noted when researching macrozoobenthos communities in the Russian section of the North Caspian Sea in 1994–1996 [Filippov, 1998].

A correlation analysis of 2006–2016 data shows a statistically significant ($p<0.05$) relation of changes in the sea level with the following data: the average annual value of total macrozoobenthos abundance; worm abundance; crustacean biomass; abundance and biomass of *Oligochaeta gen.sp.*, the polychaete *M.caspica* and *H.kowalewskii;* abundance and biomass of the mollusc *C.lamarcki;* and the biomass of the mollusc *D.trigonoides*. A similar correlation has been revealed between the above biological characteristics and environmental variables such as total organic substance content, pelite fraction content and the redox potential value of bottom sediments. In its turn, these average annual variables demonstrate a true correlation with the sea level. Therefore, it is more likely that a multicollinear dependence of the variables under consideration becomes evident. At the same time, according to our observations, a statistically significant relation between the sea level and salinity was not identified. It is possible, that this is determined by various nature of salinity fluctuations within the surveyed water body due to differences in hydrodynamic conditions.

Nevertheless, a sudden change in the qualitative and quantitative benthos characteristics in 2010–2011 is undoubtedly related to the growing salinity level in those years across the entire surveyed water area (on average above 9%). The sharp change in hydrological and hydrochemical conditions in the North Caspian Sea in the second half of 2010 was also noted by the CCHMPCS and Roshydrodromet. The abnormal seasonal drop in the sea level, the reduced Volga River inflow and increased salinity contributed into a significant reduction in abundance of small indigenous species in 2011 (Figure 8.2.6 a). The impact of euryhaline Mediterranean species, which became dominant in 2012 (especially *C.lamarcki)* has grown. The reduction of salinity has facilitated to some extent regeneration of oligochaetes and polychaete. However, the Pontic-Caspian indigenous polychaete *M.caspica* was not able to regenerate its abundance. For this reason, it is interesting to note a change in average redox potential values in 2010–2011, which may be caused by increase of organic substance content in bottom sediments (Figure 8.2.6 b). Before 2010, average redox potential values showed the predominance of oxidation processes in the upper layer of bottom sediments. Since 2011, the redox potential has fallen to negative values, which is typical for transition to regeneration conditions and the distribution of anaerobic zones in bottom sediments. It is possible that just this fact has a negative impact on abundance of the polychaete detritus eater *M.caspica*, which inhabits the upper layer of the bottom sediments (Figure 8.2.6 d).

Thus, it can be assumed that

THE CHANGES IN THE MACROZOOBENTHOS STRUCTURE IN THE SURVEYED WATER AREAS IN THE NORTH-EAST CASPIAN SEA (THE REDUCTION IN ABUNDANCE OF INDIGENOUS SPECIES, IN PARTICULAR, M.CASPICA, D.TRIGONOIDES AND H.ANGUSTICOSTATA AND THE INCREASE IN THE ROLE OF THE MEDITERRANEAN INVADERS A.OVATA, C.LAMARCKI AND H.DIVERSICOLOR) ARE RELATED PREDOMINANTLY TO NATURAL FLUCTUATIONS IN THE SEA LEVEL AND THE ASSOCIATED CHANGES IN HYDROLOGICAL AND HYDROCHEMICAL CONDITIONS.

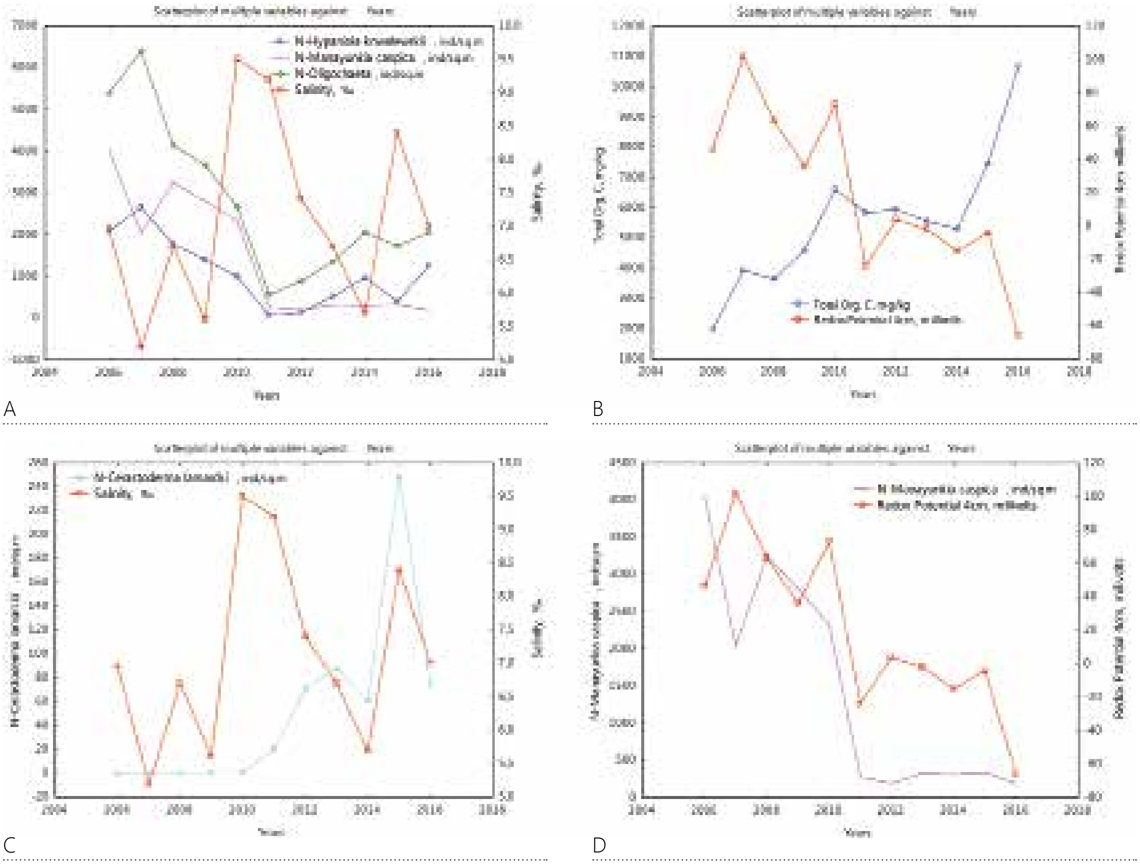


Figure 8.2.6 Dependence of changes in the main characteristics of macrozoobenthos communities on changes in salinity and the redox potential in 2006–2016

Conclusions

One hundred and seventy-five species of macrozoobenthos have been found. The crustaceans represented by 100 species make the main contribution to the community species richness. Over the years, the number of species of sea bottom invertebrates varied from 57 to 111. Average annual abundance and biomass of macrozoobenthos were 7877 specimens/m2 and 29334 mg/ m2, respectively. Worms dominated in abundance. Mollusks were the basis of the biomass of the sea bottom cenosis. The dominant complex included the worms *Oligochaeta gen.sp.*, *Hediste diversicolor*, *Manayunkia caspica*, *Hypaniola. Kowalewskii*, crustaceans of the genera *Corophium*, *Stenocuma*, *Stenogammarus*, and mollusks *Abra ovata*, *Cerastoderma lamarcki*, *Didacna trigonoides*, *Hypanis angusticostata*.

Since 2010, the abundance of autochthonous species *D.trigonoides*, *H.angusticostata*, *M.caspica* has decreased. The role of Mediterranean invaders *A.ovata*, *C.lamarcki*, *H.diversicolor* in the community has increased.

During the period of 2006–2016, the trend in reduction of the average annual macrozoobenthos abundance was evident with irregular year-to-year changes in biomass. The drop in abundance of small-sized autochthonous polychaetes *M. caspica*, *H. kowalewskii* and oligochaetes was the most pronounced.

The year-to-year dynamics of macrozoobenthos abundance depended on changes in natural factors, primarily hydrological (sea level fluctuations) and hydrochemical (salinity) parameters. The impact of anthropogenic factors on the structure of macrozoobenthos was local and short-term.

9. AQUATIC VEGETATION

Due to its bioindication properties, vegetation is an informative source of the environmental status. This Chapter reviews macrophytes, or phytobenthos of two groups of aquatic plants (phytoplankton and macrophytes). Macrophytes are plant organisms that are accessible to observation with the naked eye, regardless of their systematic identity (higher vascular, spore plants, and large algae) [Raspopov, 1992]. Macrophytes rooting or attaching to the substrate refer to phytobenthos. Substrate can be the seabed surface, objects of both natural and artificial origin, dead aquatic plants, etc.

The flora and vegetation of the North Caspian Sea and the rivers flowing into it (Volga, Zhayik (Ural)) have been studied since the 30-ies of the XX century. Surveys of aquatic vegetation were episodic, and primarily were aimed at development of a feed stock for agriculture and fishery industry. This information can be found in publications of a number of botanical researchers related to fisheries, arrangement of limans, etc. [Bogdanovskaya-Ginef, 1974; Gollerbach et al., 1953; Dobrokhotova, 1940; Dobrokhotova et al., 1982; Kassymov, 1987; Kassymov, Bagirov, 1983; Kireyeva et al., 1939; Kolbitskaya, 1977; Solntsev, 1981].

Comprehensive monitoring of environmental status, including aquatic vegetation, continued in the North Caspian Sea, as part of the environmental monitoring programs of the NCOC N.V. for 2006-2016. Also, macrophyte responses to changes in natural factors and impact of economic activities caused by development of the oil-producing infrastructure were monitored.

Survey Methodology of Aquatic Vegetation

Water flora and vegetation as objects of study involve two sciences - botanics and hydrobiology. Survey of aquatic phytocenoses was performed in accordance with geobotanical and hydrobotanical methodology as the main study guide for macrophytes with the use of some hydrobiology instruments. A number of methodology instructions have been devoted to the study of aquatic vegetation (Belavskaya, 1979; Vinogradov, 1973; Hydrobotany, 2003; Katanskaya, 1981; Raspopov, 1977].

Samples of water vegetation at depths of more than 1.5 m were taken with a large beam trawl. The collected samples were sorted by species. The area covered by a beam trawl was calculated for a certain period of time (5-10 min.). The floristic composition, features of vertical and horizontal distribution, the phytocenotic role of species, the projective covering of the seabed with plants, their phonological and vital status were defined. If necessary, the productivity in g/m^2 of dry weight was identified. In order to determine the species identity of aquatic plants, herbarium material was collected. Also, the habitat of phytocenosis was described with identification of depth, water temperature, transparency, bottom sediment properties, salinity, pH and other parameters.

At depths below 1.5 m, vegetation and its status were assessed visually, using a small beam trawl or a grabber.

Dynamics of aquatic vegetation were studied with classical methods of hydrobotanical and geobotanical surveys [Field Geobotanics, 1972].

The taxonomic identity of macrophytes was defined according to the determinants of higher aquatic plants and algae [Flora of Kazakhstan, 1959; Illustrated determinant, 1969; Determinant, 1967; Dobrokhotova et al., 1982, Gollerbakh, 1953).

Conservational status of macrophytes was defined according to the Red Book of the Kazakh SSR [Red Book, 1981]. The Latin names of higher aquatic plants were checked according to the list of S.K. Cherepanov [Cherepanov. Vascular plants, 1998].

Analysis and discussion of survey results

Over the period of surveys in the water basin and at the transit zone, over 160 species of macrophytes had been recorded under the Company's monitoring programs. They include 79 species of higher plants and 82 species of algae [Environmental Monitoring, 2014]. The higher aquatic plants (marine plants) include the most common and abundant species like barnacle grass *(Zostera marina)*, pondweeds *(Potamogeton pectinatus, P.perfoliatus, P.macrocarpus)*, parrot feathers *(Myriophyllum spicatum, M.verticullatum)*, naias *(Najas marina)*, hornweed *(Ceratophyllum demersum)*, spiral wild celery *(Valisneria spiralis)* and others. Specific habitats (from shallow to deep water) are occupied by red algae of *Polysiphonia*, *Ceramium*, *Layrencia genera*, etc., green filamentous algae of *Cladophora*, *Chaetomorpha*, *Enteromorpha*, *Oedogonium*, *Mougeotia genera*, are often found. Charophytes *(Chara polyacantha, S. Tomentosa)* occupy its niche closer to the reed beds. Diatoms and blue-green algae of *Oscillatoria*, *Cocconeis*, *Rhopalodia genera*, and others are more often involved in fouling of various objects [27].

More desalinated areas of the Volga and Zhayik (Ural) Rivers avandeltas were characterized by most floristic wealth. Representatives of the vascular plants of *Potamogeton*, *Myriophyllum*, *Najas*, *Zostera*, *Valisneria*, *Lemna*, *Ceratophyllum genera* prevailed here. Representatives of charophytes, green, red algae were often encountered. Representatives of rare species listed in the Red Book of Kazakhstan plants were also found in this area. They included *Aldrovanda vesiculosa*, Hindu Lotus, or Indian *(Nelumbo nucifera Gaertn.*), caltrop *(Trapa natans L.)*, white water lily *(Nymphaea alba L.)*, floating moss *(Salvinia natans Allioni C.)*. However, it should be noted that macrophytes registered in Kazakhstan Red Book of Plants were not encountered directly in the field area, except for autumn, 2003. During this period, specimens of freshwater relic fern *Salvinia natans* were brought into the area of artificial islands with multiple streams of the Ural River delta, which developed on the water surface. Presence of relic fern in these places was not long.

IN ADDITION TO AQUATIC PLANT-ABORIGINES, THERE ARE ALSO INVADING PLANTS IN THE NORTH CASPIAN SEA. SOME REPRESENTATIVES OF RARE SPECIES ARE INVADING PLANTS, WHICH AT DIFFERENT TIMES AND IN DIFFERENT WAYS HAVE BEEN INTRODUCED INTO THE NORTHERN PART OF THE CASPIAN SEA.

Invading Plants in the North Caspian Sea

The flora of many countries over the past centuries has changed significantly. A major part of the total number of plant species is now foreign plants (invading plants), successfully settled down in their new homeland. Invading plants or adventive species are understood to be species whose appearance in a particular area is not associated with the natural course of florogenesis. It is a direct or indirect result of human or animal activity [Richardson. Naturalization ..., 2000].

An alien species that does not have an evident negative impact in the area of a natural habitat can seriously damage the environment of a new geographic region, where it has been intentionally or unintentionally introduced.

Introduction of plant exotics can lead to the following negative consequences: competition, simplification of the structure of plant communities, hybridization processes with representatives of the local flora and other undesirable processes. This refers to both terrestrial vegetation and aquatic vegetation.

Aquatic flora in the Caspian Sea, as in many other water bodies has invading species.

The very first invading species got into the Caspian Sea during the Khvalyn time, 50 thousand years ago. They came naturally along the Kumo-Manic Strait between the Black Sea and the Caspian Sea and included 7 species of hydrobionts, specifically

– macrophyte *Zostera nana* [Change of Biological Diversity, 2017].

In the process of comprehensive impact monitoring in the North Caspian Sea (Kazakhstan territory), five modern invading species have been identified: *Aldrovanda vesiculosa L.*, *Salvinia natans Allioni C.*, *Elodea canadensis*, *Nelumbo nucifera (N. komarovii Grossh.)*, *Trapa natans* L.

Aldrovanda vesiculosa L. – is a rare aquatic insectivorous plant for the North Caspian Sea, which is the only representative in the local flora from the family of silt plants (Figure 9.1).

For the first time, the presence of this species in the North Caspian Sea was mentioned in the Article "Rare Higher Aquatic Plants of the Kazakhstan Section of the North Caspian Sea" [Stogova, 2002]. *A. vesiculosa* was discovered by the author in 1997 in the water area of the pre-reed zone and in the shallow waters between the reed islands in the interfluve of Volga-Zhayik (Ural) River.

Aldrovanda vesiculosa was previously found in the lower course of the Volga River.

The entry of *A. vesiculosa* into the North Caspian Sea probably took place with currents from the Volga River channel, waterfowls which transfer young plants getting stuck to them from one water body into another, and with water crafts.

Aldrovanda vesiculosa is sporadically spread in the continental coastal waters of all climatic zones of the Earth, excluding the most northern regions.

In Kazakhstan, the species grows in the lower reaches of the Syr-Darya and Ili Rivers. The distribution of this species is limited by the temperature regime, illumination, hydrological and hydrochemical conditions of the water body. In open areas, this predatory plant does not withstand competition with other macrophytes, and thus, no dominance and a significant increase in the abundance of this species was noted.

Floating moss *(Salvinia natans Allioni C.)* is a therophyte water fern, the only species spread throughout the northern hemisphere. It develops on the water surface (Figure 9.2).

Salvinia settles in water bodies with standing or slow flowing water. This species probably entered the Caspian Sea also from the channels

Figure 9.1 *Aldrovanda Vesiculosa L.*

Figure 9.2 *Salvinia Natans Allioni C.*

of the Volga River delta.

This species was also discovered in the North Caspian Sea in 1997, along the edge of the reed beds of the Volga-Ural interfluves.

For the first time, the presence of this species in the North Caspian Sea was mentioned in the same article as that of Aldrovanda vesiculosa [Stogova, 2002].

In 2003, single Salvinia natans Allioni C. plants were noted in the Kashagan area, almost in the center of the North-East Caspian Sea. Probably, this species was brought by currents to this part of the sea. The presence of *S.natans* in the central part of the N-E Caspian Sea was not long.

Initially, representatives of this genus grew in tropical stagnant waters in Eurasia and America, where they dominated and developed a significant biomass. Later, they were spread across Europe, in the Middle East and South-East Asia. In the former USSR, Salvinia settled in the Volga, Don, Dnepr, Kuban and other Rivers.

Currently, Salvinia is found in dead arms of rivers almost in all plains of Kazakhstan.

The distribution of this species is limited by environmental conditions of the water body, so no rapid development of this species is currently noted.

Canadian pondweed *(Elodea Canadensis Michaux)* is one of the most widespread aquatic plants on Earth (Figure 9.3).

The native land of the plant is North America, where the elodea grows in abundance in stagnant and slow flowing waters.

Elodea entered the islands of Great Britain in the 30-ies of XIX century (supposedly with timber), and has now spread to Atlantic Europe, [Ignatov, et al, 1990] the Mediterranean, Scandinavia, Asia, and Australia. In the middle latitudes of Eurasia, the eastern boundary of its artificial range extends along Western Siberia. In Eastern Siberia, Elodea Canadensis Michaux was first noted on the Yenisei River near Krasnoyarsk, as well as in the Irkutsk water reservoir [Sviridenko et al., 2013.]. In Baikal, this species was first recorded in 1980 [Maistrenko et al., 1998].

The original agents of this species entry are probably aquarists and botanical gardens. Subsequently, the distribution of Elodea Canadensis Michaux was mainly associated with water transport, fishing gear, waterfowls [Dexbach, 1951].

In northern Kazakhstan, the appearance of this species was recorded relatively late, in 1982-1985 [Sviridenko, 1986, 2000].

Regarding the Caspian Sea, this species probably came to the Caspian Sea from the channels of the Volga River delta. Elodea Canadensis Michaux was found in the North Caspian Sea water area along the edge of the reed beds of the Volga-Ural interfluves in 1997 [Stogova, 2002, Change in Biological Diversity ..., 2017]. It was a part of the phytocoenosis as an ingredient.

Elodea Canadensis Michaux is a typical example of aggressive behavior of the invading species with evident edificatory properties in new habitats. Its invasion is often accompanied by extremely negative consequences for water bodies: structural changes in biocenoses occur; general and fish productivity decreases, moreover, some cases of navigation disturbance are noted [Dobrokhotova, 1940; Dexbach, 1951, 1965; Sviridenko, 1986; Neronov et al., 2001].

Biocenoses of many water bodies in the Baikal basin, including important fishery basins, proved to be vulnerable to the Elodea Canadensis Michaux invasion. The publication of S.G. Maystrenko, et al. (1998) describes an "environmental disaster" caused by the Elodea invasion in one of the lakes of the Baikal basin (Kotokel): fish death, a multiple decrease in the overall productivity of the water body, a practical loss of fishery value.

Figure 9.3 *Elodea Canadensis Michaux*

Forecast of the spread of Elodea Canadensis Michaux in Europe in case of global warming was given in the publication devoted to the distribution of adventive aquatic plant species in Sweden [Larson, Willén, 2007]. According to the simulated scenario, this species takes a wider area of distribution than it was predicted. In all cases, the main limiting factors for the distribution of E. Canadensis are environmental conditions: temperature, light, hydrological and hydrochemical regimes of water bodies. If they change in favor of this species, an environmental disaster is possible.

Hindu Lotus, or the Indian (Caspian) (Nelumbo nucifera Gaertn.) is a relic of the Tertiary period in the Earth's history (Figure 9.4). Because of beautiful flowers reaching 25 cm in diameter, Lotus is called the "Caspian rose". Each flower lives only three days, changing its color every day from pale pink to bright purple, and when fading it leaves a funnel-shaped box with seeds.

There are different hypotheses concerning the appearance of Lotus in the Caspian Sea. Some researchers believe that Lotus has been preserved here as a relict plant since the Tertiary period. According to others, Lotus was imported into these places by wandering merchants. There is also an opinion that Lotus was brought to the Caspian Sea by migratory birds. The area of distribution of Hindu Lotus is extensive. It grows in the north-eastern part of Australia, on the islands of the Malay Archipelago, the island of Sri Lanka, the Philippine Islands, southern Japan, the Hindustan and Indochina peninsulas, and China. In Russia, Hindu Lotus is encountered in three areas: along the shores of the Caspian Sea in the Volga River delta, in the Far East, and in the Kuban estuaries on the east coast of the Azov Sea. Hindu Lotus grows in delta lakes, in bays on the seaside, along the coasts of numerous channels in shallow waters with well-warmed water.

In Kazakhstan, Hindu Lotus forms communities in the shallow area of the Volga-Ural interfluves. Its location was noted in 2000 by the researchers of the integrated field team from Atyrau.

This species is included into the Red Books of Russia and Kazakhstan. The distribution of this species is limited by the temperature regime, illumination, hydrological and hydrochemical conditions of the water body, and also by the impact of economic activity.

Water chestnut, caltrop or ling *(Trapa natans L.)*

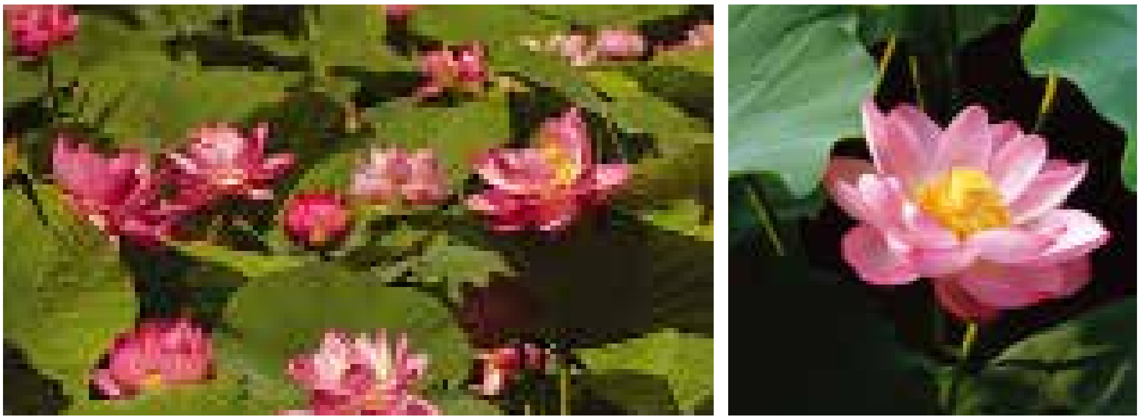


Figure 9.4 Hindu Lotus, or the Indian *(Nelumbo Nucifera Gaertn.)*

The relic of the Tertiary period. It develops on the water surface (Figure 9.5).

Excavations have shown that in the XVIII century, water chestnuts were cultivated on the coast of the Caspian Sea.

Introduction in shallow waters of the Caspian Sea contributed to the spread of this species over a wider area.

The homeland of ling is the southern regions of Africa and Eurasia. This species is widespread in the Mediterranean, the Caucasus, Central and Eastern Europe, Africa, southern Siberia, the Far East, Western Asia, Australia, and northern Kazakhstan.

Ling was included in the Red Book of the Russian SFSR, but was excluded from the Red Book of Russia (2008) due to its spread and increasing abundance. Nevertheless, it is protected in many regions at the local level, as well as in Belarus, Lithuania, Latvia, Poland, Ukraine, and Kazakhstan. This species is included in Annex I to the Berne Convention.

However, in dry Australia, water chestnut was the reason of an environmental disaster. Warm waters and the absence of natural enemies contributed to the rapid spread of water chestnut, and, in its turn, it covered the entire surface of freshwater water bodies.

Growth and distribution of water chestnut are limited by the environmental conditions of the water basin. In some countries chestnut is used as a food product, its green mass is prepared for cattle feeding. However, it is not known how this species may behave if climate changes, and consequently with changes in environmental conditions.

The sea level drop and its contamination with industrial waste cause decrease of biological resources of the sea. Due to this factor invading plants are able to use quickly "free" resources, if any (for example, in case of vegetation cover disturbance). The local vegetation species also claim for the released resources, however, invasive species are more successful because they get out of control of specific "predators" (animal phytophages) in the new places, and most importantly, of pathogenic fungi and viruses, therefore, local species lose to the invaders.

In order to stop spontaneous distribution of invading species, it is necessary to ensure a balance between the native plants and the invaders. It is very difficult to say when such balance is settled because at present the Caspian Sea environment is unstable due to climate change, fluctuation of the Caspian Sea level, anthropogenic pollution and some other important aspects. The ongoing changes in the abiotic and biotic components of the ecosystem of the Caspian Sea are in favour of invading species [Katunin et al., 1990].

Spatial distribution of aquatic vegetation and its response to natural and artificial processes

Results of environmental monitoring in 2006-2016 [Reports, 2006-2016] allowed us to analyze the status of aquatic vegetation, to define changes in the floral composition and structure of macrophyte communities, to identify the main macrophyte

Figure 9.5 Water Chestnut *(Trapa Natans L.)*

responses to natural impacts and factors caused by economic activities to develop oil and gas fields.

Monitoring was carried out at 4 fields (Kashagan, Kairan, Aktote, Kalamkas), as well as in the Oil field pipeline route area.

Review of monitoring results allowed establishing some regularities of spatial distribution of aquatic vegetation in the North-East Caspian Sea, which depend on hydrological and hydrochemical conditions of a particular habitat and are closely related to fluctuations in the sedimentation and hydrodynamic regime.

Kalamkas field is located in the open water area at 7-10 m depth of (see Chapter 2, Figure 2.2). Initially, the aquatic vegetation in the area of this field was represented by highly sparse phytocenoses with a limited species composition. Small communities and groups of eelgrass *(Zostera marina)*, benthic algae *(pp. Polysiphonia, Laurencia)* were encountered on the seabed surface of this sub-water area. Sometimes, minor concentrations of green filamentous algae were observed. Significant seabed areas not covered with vegetation were identified.

Kashagan field and an offshore section of the Oil field pipeline are located at 3.5-6.0 m. water depths. In Kashagan East the vegetation cover was mainly represented by seagrasses (higher aquatic plants) of *Myriophyllum* and P*otamogeton* genus, as well as by *Zostera marina* (Figure 9.6). Occasionally, communities and groups dominated by *Valisneria spiralis* and algae represented by small clusters, were encountered. Basically, they were red - *pp. Polysiphonia* and *Ceramium* and green filamentous algae *pp. Cladophora, Mougeotia, Chaetomorpha linum*. After storms, many macrophyte fragments, separated by the force of currents from the growing specimens of aquatic plants, were noted on the seabed surface and in the water column. Fragments of plants - torn off leaves, shoot - happen quite often due to natural processes. They are transported with masses of water at different distances. Roots are formed on the part of such fragments; the other part is carried over by currents in the form of dead plants, which gradually decompose and generate vegetation detritus.

The vegetation of Kashagan West area differs from the eastern part of Kashagan. The total projective coverage of the seabed surface by vegetation did not exceed 3-10%.

The vegetation in Kashagan West area was formed mainly at depths over 6 m and was more often represented by red algae *(Polisifonia genus)* and green filamentous algae. Sparse communities of eelgrass and single specimens of meakin were observed more rarely. Very sparse growth of groups and single specimens of the above species of aquatic plants often alternate with extensive non-overgrown areas. Accumulations of dead sea grass are encountered on the seabed surface; a lot of floating fragments of macrophytes are found in the water column and on the water surface. The total projective coverage of the seabed surface by plants, excluding non-overgrown areas in Kashagan West sub-water area did not exceed 1-3, more rarely 5%.

Kairan and Aktote fields, and an offshore section of Oil field pipeline are located at the very edge of the reed beds. The reedbed area was represented by outliers overgrown with southern reed *(Phragmites australis).* Reeds with the development of underwater outliers form a ring-type overgrown structure along the perimeter. The outliers often intergrow with each other, forming a dense barrier (Figure 9.7).

Typically, these outliers are fringed with aquatic vegetation, often dominated by *Chara tomentosa*, sometimes in combination with sea grasses *(Myriophyllum spicatum*, *M. verticillatum)* and green algae. In shallow waters, between the reed outliers, communities of sea grasses and algae are formed *(Potamogeton pectinatus*, *P. rerfoliatum*, *uruti M. verticullatum*, *M. spicatum)*. In areas more closed from currents, *Lemna trisulca*, *Chara tomentosa*, green filamentous alga *Cladophora glomerata*, *Ulotrix pseudofloecca*, *Rhizoclonium riparium*, *R. implexum*, *red algae Polisiphonia elongate*, *Laurencia caspica*, *etc.)*, are found on the surface. (Figure 9.8). The total projective coverage of the seabed by plants in different areas was from 10 % to 100 %. Also, non-overgrown areas were observed.

The coastal strip with depths of less than 1 m, where the water salinity level is the highest (6-16 ppm and above), is subject to surging processes. A shallow section of the Oil field pipeline is located in this part of the sea. In well-warmed shallow waters, the aquatic vegetation is abundant and occupies considerable areas. The total projective coverage of the seabed with plants is 30-100 %. Vegetation is represented mainly by marine plant communities, however, algae is also found. (Figure 9.9).

Closer to the shore, due to a minor seabed slope (about 0.0001), periodic flooding and down-surges form a mosaic habitat for aquatic and terrestrial vegetation. The spatial structure of the vegetation cover in shallow waters is composed of the altering coastal areas periodically flooded during surges, representing a combination of non-overgrown and overgrown grounds and shallow waters with changing depths during surging processes, as well as flooded shell islands with emerging reed communities or their beds.

Depending on the force of surges and the season of the year, coastal areas subject to flood are regularly flooded (more often in spring) and partially or completely are dried out (more often in autumn).

Both monodominant and mixed plant phytocenoses are confined to these habitats. Their alternation depends on the severity and mosaic of the seabed microrelief, lithology of the substrate, humifying and salinization conditions, location of accumulative relief forms and distance from the shore. During down-surging, the territory represents a mosaic of shallow-water habitats (in micro-depressions) and land. Thus, seasonal fluctuations in vegetation are evident here.

In spring-early summer period, macrophytes are represented by a minor abundance of green filamentous and blue-green algae *(Mougeotia sp., Microcoleus chthenoplastes)*, Chara algae *(Chara tomentosa)* and single specimens of sea grass *(Myriophyllum spicatum*, *Potamogeton pectinatus)*. During surging, fragments and single specimens of higher aquatic plants are seen on the surface in such habitats. Without water, they

Figure 9.6 Dominant sea grasses in the North Caspian Sea *(Zostera marina, Myriophyllum Spicatum).*

Figure 9.7 Outliers overgrown with reeds, and a solid barrier of intergrown outliers.

die under summer sun shine. If plants form heaps of different sizes on the surface of water, following the down-surges such plant heaps remain on the surface of the soil. Accumulations formed from aquatic plants are a kind of a greenhouse for macrophyte seeds, where moisture is retained for a long time and a certain microclimate is created. These natural hotbeds provide good conditions for seeds growing and rooting of sea grass plants *(P. pectinatus, M. spicatum)*. Communities or groups of halogrophytic plants typical for humid coastal habitats *(Salicornia europaea, Aster tripolium, Puccinellia gigantea, Aeluropus littoralis)* begin to form in areas that become free from water. These species are the pioneers of overgrowing in case of saline water bodies drying. Here, the groups of sparse reed *(Phragmites australis)* are encountered. The impact of blue-green algae *(Oscillatoria limosa, O. brevis, O. brevis var. Variabilis, O. chalybea)* results in formation of a solid crust on the surface in the area free from water (Figure 9.10). A significant part of such area free from water remains not overgrown [Stogova, 2004].

Natural phenomena (storms, surges, ice movements, etc.) can have a direct or indirect impact on development of aquatic vegetation, however, they are reversible processes and are typical for natural fluctuations.

Construction of artificial islands and other types of activities related to oil production can also have an impact on formation, development and survival of aquatic vegetation.

Figure 9.8 Green Filamentous Algae and their concentrations.

Figure 9.9 Macrophyte communities in the shallow water area

DYNAMICS OF QUALITATIVE AND QUANTITATIVE CHANGES IN THE MACROPHYTES COMMUNITIES IN THE SURVEYED WATER AREAS IN NORTH-EAST CASPIAN SEA ARE CAUSED BY FLUCTUATIONS IN THE HYDROLOGICAL, HYDROCHEMICAL AND SEDIMENTATION-HYDRODYNAMIC REGIMES, BOTH OVER THE YEARS AND ACCORDING TO THEIR SEASONS.

Natural changes in plant communities are mainly seen in minor fluctuations of abundance in the dominant group of macrophyte species and in inconsistent presence of species-constituents in the composition of communities.

The structure of bottom sediments (dimensions of the particles of the formed sediment, inclusions, compaction, inclusions of shell material, etc.) is of great importance in the formation of aquatic phytocenoses.

Analysis of the results acquired during monitoring of macrophytes in Kashagan water area, including at reference (baseline) stations (long-term observation stations – EB and baseline stations at offshore facilities – EO-EB) showed that by 2006, aquatic vegetation around operational facilities had already been partially transformed due to previous operations.

During the period 2006-2016, aquatic vegetation in Kashagan water area was found only at certain stations around offshore facilities and was represented by rare individual specimens of higher aquatic plants or their fragments transferred by currents with various combinations of algae.

Low abundance of aquatic vegetation or its absence on the seabed surface of Kashagan water area was noted in different years and seasons. Partially, natural processes contributed into it and resulted in significant adjustments of macrophytes development. Operational activities related to construction, laying, installation and dismantling of facilities had a direct and indirect impact on aquatic vegetation. This fact is well traced at stations around artificial islands A and D.

During the period 2006-2010, aquatic vegetation around D island was found only at 2 stations in 2006, and at 1 station in 2009, taking into account the baseline station EO-EV9, located at a short distance from the island and was part of the Island's survey water area. Only in 2006, at KED-1200/245 station, the aquatic vegetation was represented by single specimens of sea grass with accumulations of green filamentous algae *(Potamogeton pectinatus, Myriophyllum*

Figure 9.10 Crust of the surface layer in the area free from water with Blue-Green Algae

spicatum, Chaetomorpha linum, C. vagabunda, C. globulina, C. glomerata, Enteromorpha flexuosa, E. clathrata, Vaucheria intermedia). At other stations, macrophytes were represented by minor accumulations of green filamentous algae, rarely by dead red algae. No vegetation was found during this period around this island, [Stogova, 2004]. During the period 2011-2016, the aquatic vegetation around islands A and D was noted in different seasons and different years. They were accumulations of algae, fragments of higher aquatic plants brought by currents from other habitats and dead macrophytes.

Certain processes are formed with increase of navigation and construction activities that can have a negative impact on formation and development of vegetation in local areas.

In addition to direct destruction of vegetation cover caused by dredging operations, trenching for pipelines, construction of islands and other activities, one of the strongest impacts on macrophytes is the siltation of the seabed surface around offshore facilities leading to a change in the biotope.

The change of biotope around artificial islands in Kashagan field contributed into qualitative and quantitative changes in the vegetation cover. Currently, no water vegetation is noted, or it is at different stages of transformation, around A and D islands and in the area of other offshore artificial facilities. Accumulations of algae, not observed here previously or noted in minor abundance (green filamentous, blue-green, red, yellow-green, siphon, and etc.) began to appear in the formed biotopes.

During 2006-2010, vegetation was observed in Kashagan West water area only at 2 stations with single specimens of sea grasses that were at the stage of vegetation [Stogova, 2004]. During the period 2011-2016, no water vegetation in this part of the sea was found at all.

Colonies of red and green algae forming fouling on solid surfaces are generated on the stony lateral slopes of artificial offshore structures (Figure 9.11).

Intensity of operations in Kashagan West water area was much lower (artificial islands were not built, only a few wells were drilled) than in the eastern part of the field. It is more likely that the main impact on the existinge vegetation was made by natural processes. Economic activity has not had an impact on macrophytes due to their strong sparsity or absence on the seabed surface.

Water vegetation at long-term baseline stations (EB-series stations) during the period 2006-2010 consisted of individual specimens of higher aquatic plants *(P. pectinatus, M. spicatum, Z. marina)*, their fragments and accumulations of green filamentous algae.

During the period 2011-2016, macrophytes were identified only in 2011 and 2012, and were represented by sparse single specimens of higher aquatic plants and their fragments, introduced by currents, and also by accumulations of algae.

During the period 2006-2010 accumulation of algae and certain fragments of sea plant grasses introduced by currents prevailed at baseline stations (EO-EB). In 2011, the vegetation at these stations consisted mainly of single rare specimens of higher aquatic plants (meakin and eelgrass). In 2012, sea grasses were noted only at 2 stations; in other water area, only algae accumulations and fragments of sea grasses introduced by currents were noticed. In some areas, seabed surface was covered with dead plants.

Diatomaceous, golden and other algae *(Synedra tabylata, Diploneis smithii, Ulotrix flacea, Protosiphon botioides)* are noted in fouling at dead macrophytes.

Water vegetation along the route of Oil field pipeline was not evenly distributed. This is due to differences in habitat conditions. After completion of Oil field pipeline construction (2008-2009) the aquatic vegetation quickly recovered in a deeper section of the Oil field pipeline. By 2012, it was represented by rare individual specimens of sea grasses with the involvement of different algae (*M. spicatum*, *C. glomerata*, *Protosiphon boteyoides*, *Grammatophora sp.*, *Diploneis smithii)*, as well as fragments thereof. Before 2014, some specimens of higher aquatic plants were still observed. By 2015-2016, the aquatic vegetation consisted only of fragments of sea grass introduced by currents, often with accumulations of algae (green, red, and etc.) developing directly on dead plants (Tables 9-1 and 9-2). The laying of Oil field pipeline in a deeper section of the route had a temporary local impact on aquatic vegetation. Due to natural processes there was a rapid smoothening of the seabed surface and complete or partial rehabilitation of vegetation.

Construction of Oil field pipeline in the water area of the reed belt and in pre-reed beds section destroyed a considerable part of the aquatic vegetation and strongly transformed it. Survived single specimens and accumulations of green filamentous algae with the involvement of diatoms in fouling (*Cladophora glomerata*, *Diploneis smithii*, *Navicula halophila*, *Cymbella lanceolata*, *C. turgata*, *Coscinodiscus jonesianus Navicula salinarum*, *Hantzschia crassa*, *Diatoma vulgare*, *Bacillaria paradoxa)* started to develop on the seabed surface, where vegetation communities with predominance of sea grasses were previously located. In 2014, at a number of stations of Oil field pipeline route (NP03-500/E, NP03-1500/E, NP03-1500/W), in the pre-reed section of the sea, single specimens of higher aquatic plants were found.

Remediation of aquatic vegetation in this part of the sea is much slower than in the deeper section. This part of the sea is exposed to specific natural processes. Multilayer rows of reeds suppress the wave energy and a large volume of fine sand and silt fractions settle onto the sea bottom. Compacted bottom sediments are formed under the pressure of movements of the water masses. Probably, it will take some time before aquatic vegetation is restored in the described habitats, since remediation will occur mainly on the basis of seed materials.

No aquatic vegetation from 2009 to 2012 was found in the area of the Oil field pipeline route crossing the shallow water section after completion of its construction. In 2013-2014, the presence of rare single specimens of sea grass and small accumulations of green filamentous, was noted more rarely than the red algae. In 2016, the seabed surface was covered with dead grass by 20-40%. No vegetation was observed in this area.

Figure 9.11 Fouling of artificial islands with macrophytes

Table 9-1 Dynamics of aquatic vegetation along the Oil field pipeline route for 2006-2012

Monitoring stations	2006 spring	2007 autumn	2008 spring	2009 autumn	2010 spring	*2011	2012 spring
deeper water section							
NP-F1				light green			
NP-F1-E1K	light green				light green		light green
NP-F1-E6K	light green				light green		
NP-F1-W1K	light green				light green		pale green
NP-F1-W6K							pale green
pre-reed beds section							
NP-F5	dark green	dark green	dark green	light green	light green		
NP-F5-E400	dark green	dark green	dark green		light green		
NP-F5-E1K	dark green	dark green	dark green		yellow		
NP-F5-E6K	light green	dark green	light green		brown		yellow
NP-F5-W400	light green	dark green	dark green				
NP-F5-W1K	light green	light green	dark green				
NP-F5-W6K	light green	light green	dark green		light green		
NP-F8			dark green				
shallow section and transition zone							
NP-F11A	dark green		dark green				
NP-F11-E400A	dark green	dark green	dark green				
NP-F11-E1KA	dark green	dark green	light green				
NP-F11-E6KA	dark green	light green	light green				
NP-F11-W400A	dark green	dark green	dark green				
NP-F11-W1KA	dark green	dark green					
NP-F11-W6KA	dark green	dark green					
NP-F13A		dark green					
NP-F13-E400A	light green	dark green					
NP-F13-E1KA	dark green	dark green	dark green				
NP-F13-E6K	light green	dark green					
NP-F13-W400A	light green	dark green	dark green				
NP-F13-W1KA	dark green	dark green	dark green				
NP-F13-W6K	light green						

Note: * During the years marked with an asterisk, botanical surveys were conducted, however, no vegetation was identified.

Legend

- (dark green) Community of higher aquatic plants
- (light green) Rare single specimens of higher aquatic plants and small accumulations of green filamentous, rarely red algae
- (pale green) Fragments of higher aquatic plants and other macrophytes
- (yellow) Single small clusters of green filamentous algae, often with the involvement of blue-green, yellow-green algae, with epiphytic species and fouling
- (brown) Macrophyte starnik, vegetable detritus

Table 9-2 Dynamics of aquatic vegetation in the Oil field pipeline sections for the period 2013-2016

Years	2013			2014			2015			2016		
Stations	Spring	*Summer	Autumn	Spring	Summer	*Autumn	Spring	Summer	*Autumn	Spring	Summer	Autumn
deeper water section												
NP01-500/W						light green	light green					
NP01-550/E												light green
NP01-550/W												light green
NP01-1500/E			green									
NP02-550/W								light green		light green	light green	
NP02-550/E			green								light green	light green
NP02-1000/W				light green							light green	
NP02-1500/E					light green			light green			light green	light green
NP02-1500/W				light green	green			orange				light green
pre-reed beds section												
NP03-500/E					dark green							
NP03-550/E												light green
NP03-1500/E				light green	dark green							
NP03-550/W							light green					light green
NP03-1500/W					dark green						light green	light green
shallow section and transition zone												
NP04-1500/E					orange						light green	light green
NP04-1500/W	brown		green								light green	light green
NP04-550/E											light green	light green
NP04-550/W			green								light green	light green

* During the seasons marked with an asterisk, botanical surveys were conducted, but no vegetation was identified

Legend

- (dark green) Community of higher aquatic plants
- (green) Single specimens of higher aquatic plants and small accumulations of green filamentous, rarely red algae
- (orange) Small accumulations of green filamentous algae, sometimes with the involvement of blue-green, yellow-green algae, with fouling.
- (light green) Fragments of higher aquatic plants and other macrophytes
- (brown) Macrophyte starnik, vegetable detritus

IN OUR OPINION, THE MAIN REASON FOR VEGETATION ABSENCE IN THE SHALLOW SECTION OF THE OIL FIELD PIPELINE ROUTE IS A TREND IN THE CASPIAN SEA LEVEL DROP.

Currently, due to a slight slope of the seabed surface (about 0,0001), the land gradually seizes the areas of the former transition zone (or transit zone), which earlier were under water during the rise of the sea level. In other words, in addition to seasonal and interannual changes in development of aquatic vegetation caused by natural factors and economic influences, there are also long-term (secular) changes in the natural vegetation. The presence of non-rooting fragments of macrophytes and dead plants that move along the surface of the soil in the direction of the shore and back, depending on the water currents (surges), do not give any indication of remediation processes in aquatic vegetation in the near future. Perhaps, in the future this territory will be covered by land vegetation, as it was before.

Aquatic vegetation around Kairan and Aktote artificial islands in 2006-2016 was represented only by rare fragments of higher aquatic plants, dead plants and clusters of algae. No vegetation generated in these areas was observed. After completion of construction of Kairan and Aktote artificial islands (2000-2002), the seabed surface composed of compacted gray (in some places, black) silt with an admixture of broken and entire shell was formed; often during the sampling of bottom sediments a continuous smell of hydrogen sulfide was felt. The vegetation around these islands has not been formed, despite the shallow depths and multiple introduced fragments of higher aquatic plants, ready to take root. One of the reasons for absence of aquatic phytocenoses in this part of the sea is proximity to the reed belt. Reed beds suppress the wave energy, thus contributing to transfer of silt masses and fine sand onto the seabed surface. Introduced bottom sediments form dense bottom sediments where vegetative restoration of aquatic plants becomes difficult.

Aquatic vegetation in Kalamkas water area is rather scanty. There are many areas without vegetation in this part of the sea. During the period 2006-2016, groups and communities of red algae of *Polysiphonia* and *Laurencia* and their dead plants, often together with fragments of higher aquatic plants introduced with currents, were represented in a minor abundance at single stations. Epiphytic forms of algae and multiple fouling were encountered on dead macrophytes. Occasionally, small areas of sparse communities and single specimens of the eelgrass *(Zostera marina)* were encountered. In 2016, no macrophytes on the seabed surface at Kalamkas field were found in any season.

At the long-term baseline station (G) in Kalamkas aquatic vegetation was recorded in different seasons 2009-2015 only in the form of individual specimens of red algae, dead red algae and fragments of higher water plants introduced by currents. No formed communities, groups of higher aquatic plants or red algae were identified here. Probably, station G is located in a habitat that was initially deprived of a possibility to generate phytocoenoses for various environmental reasons.

Conclusions

The natural environment of the Caspian Sea is unstable due to climate changes, sea level fluctuating features and some other important aspects of impact. The ongoing changes in the abiotic and biotic components of the ecosystem of the Caspian Sea cause the lack of balance between the aboriginal plants and invading species, and thus supporting invaders. Under prevailing environmental conditions for any plant-invader, its rapid development can lead to an "environmental disaster".

Currently, there is no aquatic vegetation around offshore artificial structures at Kashagan field, or it is at different stages of transformation. The appearance of algal clusters around offshore structures is noted, including those previously not observed (blue-green, yellow-green, siphon, etc.), and an abundance of macrophytes fragments brought by sea currents, has been recorded around offshore facilities.

Colonies of red and green algae generating fouling on solid surfaces are formed on the stony lateral slopes of artificial offshore facilities.

Little intensive economic activity was carried out in the western part of Kashagan field, and due to very sparse aquatic vegetation and considerable areas of the seabed without it, such activity had almost no impact on vegetation.

Baseline stations located far from the offshore facilities and navigation routes are exposed only to impacts of natural processes. In some part of baseline stations in Kashagan area, due to proximity of ongoing economic operations, the aquatic vegetation has been transformed. According to our data, after the completion of construction works in deep sea areas, the status of aquatic vegetation will be stabilized in the next few years.

Construction of Oil Field Pipeline at deep water sites had a temporary local impact on macrophytes. Due to natural processes, there was a rapid smoothing of the seabed surface and full or partial remediation of vegetation.

In our opinion, the main role in remediation of the aquatic vegetation along the pipeline route in the shallow section was the emerging trend of the Caspian Sea level drop. Perhaps in the future, a considerable part of this territory will be covered by the land vegetation, as it was before the period of the last transgression of the Caspian Sea.

One of the reasons for absence of aquatic vegetation around Kairan and Aktote artificial islands is the proximity to the reed belt. Silt masses and accumulations of decomposing dead plants brought onto the seabed surface under the influence of the shock force of waves facilitate formation of dense bottom sediments in this part of the sea. Vegetation in these habitats is almost not restored in a vegetative manner. Seed restoration can take longer time.

Environmental monitoring of Kalamkas field has allowed identifying small areas of sparse communities and single specimens of the eelgrass *(Zostera marina)*, alongside with groups of red algae. No vegetation was found at the baseline station G in this field, since this station is located on a non-overgrown seabed surface.

10. ICHTHYOFAUNA

The current ichthyofauna in the Caspian Sea is not as diverse in species as it is in open seas and it consists predominantly of indigenous species. It includes 139 species and subspecies of fish and fishlike, with five species registered in the Red Book of the Republic of Kazakhstan. Sturgeons such as beluga, common sturgeon and stellate sturgeon; carp such as the roach, bream and the common carp; perch such as zander; and herring such as sprats and herring are of the highest value.

The Caspian Sea with the lower reaches of rivers flowing into it is the most important fishery water basin in the Republic of Kazakhstan, where approximately 0.3 million tons of fish are caught every year. Many Caspian species of fish, including sturgeon, herring and sprats are important for commercial fishing. They belong to transborder species with the Caspian Sea as their general habitat.

According to researchers, fluctuations in the sea level, salinity patterns and volume of rivers' inflow have the most considerable impact on ichthyofauna diversity. Short-term changes in the sea level are caused by volumes of water inflow from the Volga and Zhaiyk (Ural) Rivers, which have a long-term and even century-long cyclic nature as a result of global climate changes. In the last 500 years the range of these fluctuations has been approximately 7 m [The Caspian Sea, 1998, TDA, 1998, 2002].

Changes in environmental conditions (regulated rivers inflow, increas of irrevocable water consumption, pollution, etc.) and human economic activities cause fluctuations of valuable commercial fish stock. Violations of natural hydrological regime of the Volga and Zhaiyk (Ural) rivers and operation of counter-regulators have resulted in annual losses of over 180,000 tons of valuable commercial species of fish. The Kura, Sulak, Terek and Samur Rivers have significantly lost their commercial fishery importance.

ACCORDING TO OPINION OF THE MAJORITY OF EXPERTS, A MAJOR PART OF POLLUTANTS COMES TO THE NORTH CASPIAN SEA WITH THE VOLGA AND ZHAIYK RIVERS INFLOW. COASTAL OIL FIELDS TOGETHER WITH ABANDONED WELLS ALSO PLAY A SIGNIFICANT ROLE IN THE NORTH-EAST CASPIAN SEA POLLUTION.

According to Russian researchers, by the end of 2000, the volume of pollutants entering the North Caspian Sea with the Volga inflow amounted to 29.6 thousand tons of petroleum hydrocarbons, 0.30 of phenols, 9.76 of synthetic surfactants, 7.0 of zinc, 1.62 of copper, 1.01 of lead, 0.089 of cadmium, 1.39 of manganese, 0.326 of nickel and 0.335 thousand tons of cobalt [Katunin et al 2002]. According to the data at the Federal PROTOWN.RU website, in 2004 the volume of pollutants entering the North Caspian Sea with the Ural inflow amounted to 0.03 thousand tons of petroleum hydrocarbons, 0.40 tons of phenols, 2.55 tons of synthetic surfactants, 7.88 tons of zinc, 1.03 tons of copper, 2.91 tons of manganese and 0.14 tons of nickel [PROTOWN.RU, 2004]. Therefore, the Volga river inflow brings 986 times more petroleum products, 4 times more synthetic surfactants, 1.6 times more copper and 2.3 times more nickel than the Zhaiyk river inflow.

In the near future (by 2030), the Caspian Sea pollution can increase. We need to realize that pollutants volume will grow alongside with the level of economic development in the relevant river basins and the Caspian Sea water area. Marine environment pollution through air pollution, offshore incidents and water filtration from the numerous coastal facilities, and from direct discharges of preliminarily treated waste water into the sea will also grow [Kim, 2010; Katunin et al, 2006].

In accordance with the Law of the Republic of Kazakhstan *On Subsoil and Subsoil Use* and Governmental Resolutions, offshore petroleum operations include geophysical surveys and exploration, oil and gas production activities and any related storage, oil and gas transportation by pipelines from offshore to onshore, construction, installation and support to offshore facilities functioning [Law of the Republic of Kazakhstan N291-IV dated 24 June 2010 *On Subsoil and Subsoil Use* as amended].

Atyrau Oblast is one of the hydrocarbon production regions where major offshore oil fields such as Kashagan, Zhambai, Satpayev and others are located (see Chapter 1 Figure 1.1.). Geological exploration work is performed in the North-East Caspian Sea water area to produce petroleum hydrocarbons. It is also an intensive transportation area connecting intended production locations with a number of ports.

Practice of oil and gas industry facilities engineering and construction indicates that routine operations do not impose any risk to the environment. Project engineering and construction methods shall ensure a high reliability and environmental safety during construction and operation. However, even if all safety requirements are met and highly-qualified staff is involved, a possibility of incidents resulting in emergency oil blowouts still exists.

The sea bed is also disturbed during construction of berms (or islands) for well drilling and pipelines laying which represents a man-caused impact on marine biota.

Surveys performed during the exploration period and construction of islands at offshore fields have demonstrated that the North Caspian Sea benthos is generally adaptive to increased concentrations of suspended particles, while adult fish is able to leave the exposed area during construction of offshore islands and pipelines [Matischev et al, 1997].

In the last century, with the sea level drop and salinity increase, the changes affected the various elements of the marine ecosystem. The whole groups of freshwater and brackish water species have disappeared from the phytoplankton, zooplankton and benthos communities, while a number of marine species that better adapt to higher salinity had increased. Freshwater and brackish water species of plants and aquatic organisms were concentrated in the desalted zone of the Volga and Ural coastal area. Reproductive freshwater species such as bream, rudd, asp, common carp and others were in decline. With reliction of the sea, all coastal vegetation vanished and the number of bird species nesting previously in water vegetation brushwood had decreased significantly.

THE INCREASE OF THE SEA AREA DURING THE LAST RISE IN THE SEA LEVEL (1978–2004) SIGNIFICANTLY EXPANDED THE BORDERS OF FISH FEEDING GROUNDS AND IMPROVED NATURAL REPRODUCTION IN THE SEA BREEDING GROUNDS.

With the rise of the sea level, the reed belt stretching from the Volga delta to the Komsomolets bay was formed in the coastal zone. In certain areas the width of the reed belt reached 10–15 km.

Before the start of rivers regulation, the Zhaiyk and Volga, their river beds, their branched deltas and the North Caspian Sea represented a single natural hydrological complex providing all necessary conditions for natural spawning of fish, roe development and incubation, timely fry emigration and the subsequent feeding of young and adult fish in highly productive feeding grounds in the North Caspian Sea and surrounding pre-estuary areas. All fish currently included in the Red Book or under the over-fishing status, used to be usual commercial species. The sturgeon catch reached 35,000–37,000 tons, Volga migratory herring and migratory black-backed herring catches reached 270,000–350,000 tons, Caspian salmon — 1,200–1,000 tons, Nelma — 2,200–2,500 tons, and traditional "ordinary" fish, such as roach, common carp, bream, zander and pike — 200,000–260,000 tons [Makhmudbekov, 1956; Letichevskii, 1963, 1973 and 1978].

Following the completion of construction of hydro-electric stations on the Volga, Kura and Atrek rivers and counter-regulator dams in the Zhaiyk river upstream (within the boundaries of Russia), the environmental conditions for existence and breeding of river, migratory and semi-migratory Caspian fish had changed significantly. Regulation of rivers inflow resulted in decrease of maximum standing levels of floodwaters, spring high waters and reduction of the floodplain period with worsening of temperature conditions in the spawning grounds and reducing the bio production stock volumes [Vinetskaya, 1962; Caspian Sea..., 1989; Katunin, 1992]. Under such conditions, North-Caspian fish catches decreased significantly, i.e. roach catch decreased by 77.0%, zander by 92%, bream by 61% and pike by 58% [Ivanov 2000; Zykov, 2001 and 2005].

THE MAIN REASON FOR FISH RESERVES REDUCTION FOLLOWING THE START OF THE RIVERS REGULATION WAS DISTURBANCE IN THEIR NATURAL REPRODUCTION UNDER NEW HYDROLOGICAL CONDITIONS.

The rivers regulation resulted in significant decrease of flooded spawning areas in the midstream and downstream sections of the Zhaiyk and Volga rivers. Spawning areas for sturgeon in the Zhaiyk and Volga rivers and spawning areas for zander, roach, bream and common carp in the pre-estuary water area had decreased.

Volcanic events in the Derben depression were seen as the main cause of death and reduction of Black Sea-Caspian and anchovy sprat stock at the beginning of the new millennium [Katunin et al, 2002].

Improper fishing is recognized as one of the main reasons for the fish stock reduction and the main risk to biodiversity. The overfishing of certain species had resulted in economic losses and misbalance of environmental, feeding and other relations which restoration can take many years. This has been the case with the Caspian salmon, the Volga herring, sheefish, which are now included in the Red Book. It is assumed that prior to the rivers regulation, overfishing was the main cause of reduction in their abundance. Specifically, at the beginning of the previous century, sheefish catch in the Volga-Caspian basin reached 2,800–3,200 tons, while currently it totals maximum 1,500–2,000 tons [Caspian Sea...., 1989]. Sheefish catch is currently forbidden, and its stock replenishment is ongoing.

Caspian sturgeon is the most striking example of improper (excessive) fishing. During the last century, Caspian sturgeon catch experienced significant changes caused by natural and man-caused factors. However, the major impact on sturgeon stock was caused by overfishing [Kamelov, 2009]. In the period 1900–2010 the sturgeon catches in the Caspian Sea had decreased from 37,000 tons to several dozen tons (Figure 10.1.1).

The above Figure clearly shows that very high catch periods alterate with sharp declines, which is an undeniable indication of the excessive fishing of commercial species. The last catch peak was observed in the 1980s which was followed by significant reduction of natural reproduction.

Sturgeon (Acipenseridae family) is included in the Convention on International Trade in Endangered Species (CITES). At present Kazakhstan has a moratorium on sturgeon fishing.

According to scientists, the main reasons of reduction in sturgeon abundance are the following: [Atyrau Oblast Administration 2012; The Caspian Sea, 1989; Comprehensive surveys 2008–2016]:

- Improper fishing (legal and poaching)
- Rivers regulation
- The Caspian Sea pollution
- Lowering of the Zhaiyk River water content
- Decrease in spawning grounds.

Herewith, the first three key factors are man-caused and only the Zhaiyk river water content lowering and subsequent spawning areas decrease are natural.

Thus, a range of both natural and man-caused factors have impact on the biodiversity of the North Caspian Sea and flora and fauna quantitate variables which cause an integrated impact on biota.

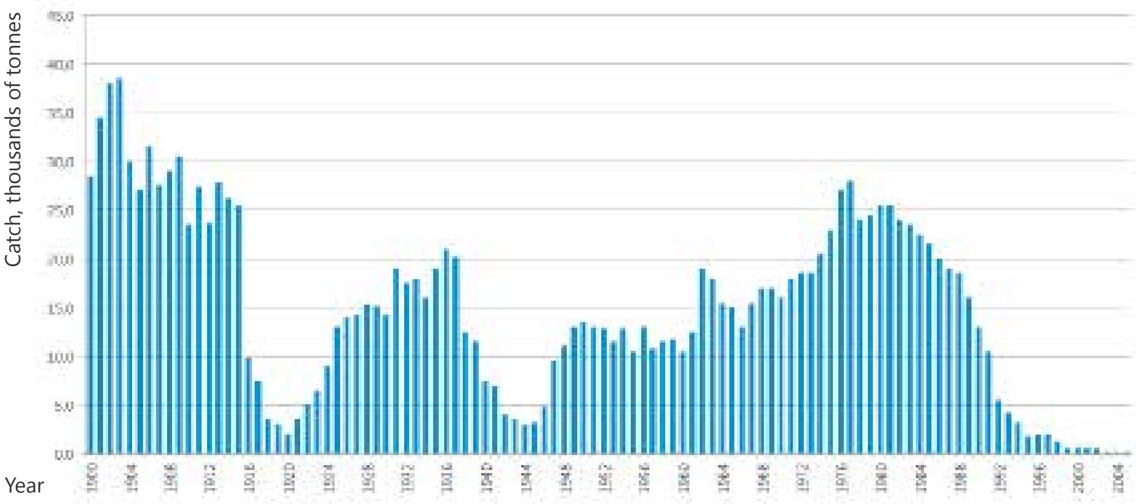


Figure 10.1. Dynamics of sturgeon catches in the Caspian Basin in the period 1900–2010

10.1 Results of ichthyofauna monitoring in the Company's Contract Area waters in the period of 2006–2016

This Section has been prepared based on environmental baseline and monitoring surveys of the North Caspian Sea [Offshore Environmental Surveys in 2006–2015; 2015–2016], performed within NCOC B.V. Contract Areas in 2006–2016.

The monitoring process has its specifics and requirements that make it different from other types of surveys, such as:

- Regular observations at fixed monitoring points (stations)
- Harmonization and standardization of observation tools and methods
- Efficiency of analysis and interpretation of observable changes to identify any ongoing changes and timely response.

Such requirements slightly narrow the scope of surveys and limit opportunities for survey performance, however, allow to obtain comparable data on dynamics of ongoing changes in the areas under survey.

10.1.1 Fishing methods and gear

Ichthyofauna is the most commercially valuable element of the marine biological environment of the Caspian Sea. At the same time, fish is a very mobile component and able to move (migrate) independently and intentionally for a long distance, sometimes hundreds of kilometers. During migration a temporary (seasonal) increase of fish abundance occurs within various sea areas subject to biological characteristics of certain species and population. Together with the mobile ichthyofauna species, there is also non-mobile and "settled" fish, mainly from the goby and pipefish family with a bottom life pattern. Such ichthyofauna features have their advantages and disadvantages for the fish as the object of the marine environmental monitoring.

The most mobile elements of ichthyofauna including all commercial fish species can quickly respond to adverse environmental impact and leave impact areas immediately. It means that fish can be considered as an ideal indicator of changes in the marine environment, which can have a local or short-term nature. The disadvantages of this monitoring object can include seasonal changes in fish concentrations caused by special features of its life cycles and its quick response to natural changes in the water environment (abrupt temperature changes, storms and surge events), which frequently makes it difficult to identify a man-caused component of adverse impact.

Non-mobile bottom fish species are unable to leave adverse impact areas quickly, and thus, their abundance changes only either as a result of death or by slow and gradual migration from the impact area. Therefore, these fish species can serve as a better indicator of any hazardous or long-lasting adverse impact on the marine environment. The disadvantage of this indicator is a high potential survival of bottom species, their adaptation to unfavorable conditions, and slow response to impact. This can result in a temporary discontinuity between the impact and response to it. In its turn, it can make difficult to identify the source of impact.

Two types of fishing gear were used to ensure the widest range of "catch" of ichthyofauna representatives; firstly, passive fishing gear, like standard fixed gill nets with different mesh sizes and active fishing gear – bottom trawls (beam trawls).

Fishing with fixed gill nets is one of the most efficient methods of collecting material to monitor ichthyofauna (Figure 10.1.1). It is ensured through a reliable fish catch with use of mesh size specific for a particular fish species and nets setting for several hours. Fish catch is arranged with use of the so-called standard set of nets with mesh size that varies from 14–16 to 100–150 mm ensuring efficient catch of any sizes of fish groups. The "gill" principle in gill nets provides catch of fish actively moving through the water column. That is why the total number of fish caught by a standard set of nets is called nekton (swimming) fish community and catch volume is measured according to the relative units per effort. Fixed nets are a passive fishing gear which efficiency depends on many factors with the following main factors:

- Material, colour and thickness of the net mesh fiber
- Size of the net mesh
- Fabric mounting level when manufacturing ready nets
- Size of net fabric in ready nets (net length and height)
- Degree of net fabric tension following the nets setting in the water body (ratio of cargo weight and carrying capacity of floats)

The following external factors have impact on net catch efficiency:

- Water transparency
- Day time (lighting)
- Fish migration activity change (due to water temperature, migration period, lighting,

Figure 10.1.1 Setting of gill nets for ichthyofauna monitoring

disturbance and others)

- Weather conditions (storm, surges and ice drifting)
- Water body depth in the place of nets setting, if it is shallower or significantly deeper than the web fabric height
- Overgrowing of the water body with algae and high aquatic vegetation

The main disadvantages of the net fishing method are long duration (exposition) of one catch, which restricts efficiency in getting the primary data, reduces the potential number of sampling stations and hinders the objective assessment of catch quantitative variables for a specific water area. However, the use of gill nets is quite sufficient to get comparable data and trace the dynamics of changes during ichthyofauna monitoring.

Bottom beam-trawls are used to catch fish in bottom waters (Figure 10.1.2) The trawl catch includes mainly inactive fish from the goby family and fish youngsters from the nekton community, which prefer to stay and feed in bottom waters. Such group of fish is called tentatively as benthopelagic fish community in monitoring surveys [Litvenkova, 2011]. Efficiency of beam-trawl catching depends on trawling speed, which should be at least 1 m/s (2 knots) and cod end mesh size. The advantages of this method are efficiency, mobility and short duration of the sample collection process (about 10 minutes) and consequent receipt of the data on fish quantitative variables per unit of the bottom area. The disadvantages include exposure to natural or artificial bottom obstacles, the relatively small catch area and, consequently, a high probability of "empty" catches.

During 11 years of monitoring, 602 settings of nets and 2,730 trawling with bottom trawls (beam trawls) were performed (Table10.1-1). Nets settings were at its lowest in 2011–2012 and highest in 2016. The lowest number of trawls was in 2007 due to non-performance of observations in the spring period. The highest number of trawl catches was in 2015.It should be noted that this Table provides the data for all years (2006–2016) and all seasons, for all sampling stations, for 4 fields — Kashagan, Kalamkas-sea (further — Kalamkas), Kairan and Aktote, and Oil field pipeline route.

Figure 10.1.2 Lifting a beam-trawl aboard after trawling

Table 10.1-1 Number of ichthyofauna samples taken in the North-East Caspian Sea area under the survey in 2006–2016

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Nets settings												
Spring	30	-	35	21	19	-	-	26	27	27	59	244
Summer	-	-	-	-	-	-	-	35	27	23	33	118
Autumn	27	16	30	40	11	13	-	27	23	22	31	240
Total	**57**	**16**	**65**	**61**	**30**	**13**	**-**	**88**	**77**	**72**	**123**	**602**
Trawling												
Spring	87	-	79	48	106	49	75	163	159	174	108	1048
Summer	-	-	-	-	-	-	-	168	159	176	113	616
Autumn	50	58	65	81	97	97	85	85	159	176	113	1066
Total	**137**	**58**	**144**	**129**	**203**	**146**	**160**	**416**	**477**	**526**	**334**	**2730**

Separately, only dynamics of ichthyofauna abundance was analyzed per locations. Thus, description and conclusions for the nekton community were provided for Kashagan East which is considered to be the area of the highest operational activity. The most representative material in terms of benthopelagic community abundance was collected at three locations — Kashagan East, the Oil field pipeline route and Kalamkas.

10.2.2 Ichthyofauna biodiversity and quantitative variables

The Caspian Sea ichthyofauna is highly non-homogenous and diverse, both in terms of individual sizes and life pattern; from gigantic beluga sturgeon and catfish to three-cm goby and from highly migratory herring to non-migratory needlefish. During the monitoring period of the North Caspian Sea ichthyofauna, in total 70 species and subspecies of fish have been identified, which accounts for over 50% of the referenced composition of fish inhabiting the Caspian Sea. The similarity quotient for the species composition of nekton and benthopelagic community (the equivalent of the Jaccard index) is 46% [Rozenberg, 2012]. This means that approximately half of the 70 species and subspecies are found in both fish communities. Fish species such as roach, bream, white-eye bream, sabre fish, zander, and three species of shad are found in net and trawls catches practically every year and differ in terms of size only. Certain fish species are found predominantly in one fish community. As such, golden carp, common carp, grey mullet and golden mullet tend to be found in net catches, while Black Sea and Caspian sprat, sand smelt and many species of goby are predominantly found in beam-trawl bottom catches. There are other species of fish that are unlikely or accidentally to be caught by means of other types of fishing gear. They include stellate sturgeon and Persian sturgeon (three specimens in 10 years) caught by beam trawls, and Knipowitschia iljini, bighead goby, Makhmudbeyev gobies, star gobies and needle fish caught with fixed nets (once during the observation period). There are species that are specific only for one fish community. The majority of sturgeon, sea and migratory herring, pike and catfish species are only found in net catches, while tiny gobies and big head gobies were only found in bottom trawl catches. And finally, there are also species of fish with minor abundance and can be rarely found in the North Caspian Sea water area, irrespectively of the fishing gear used. With reference to the nekton community, they include barbel sturgeon, sterlet, Black Sea roach, nerfling, tench, Crucian carp, perch and Ukrainian stickleback, and for the benthopelagic community they include Caspian shemaya, spined loach, Kazakh big head gobies, benthophilus leptocephalus and short-snout gobies.

Species composition of the nekton community in control catches with fixed nets in the water area in 2006–2016 included 44 fish species and subspecies from 9 orders and 10 families (Annex 7, Table A1). The majority of fish species belonged to the carp (14 species), goby (10 species), herring (7 species) and sturgeon (5 species) families. The number of species from other families did not exceed 3. The species composition of nekton fish was the richest in 2006 and 2008, with 30 and

32 species respectively. The lowest number of fish species was caught in 2007, 2011 and 2013 (16–17 species).

53 species and subspecies of fish from 7 orders and 9 families were identified in the species composition of the benthopelagic community (Annex 7, Table A2). The richest families in species terms were the goby family (29 species), the carp family (11 species) and the herring family (5 species). The number of species in other families did not exceed 2. The highest number of species in the benthopelagic community was seen in 2008 and 2009, with 35 species in each year. The lowest numbers were recorded in 2007 and 2011 (21 and 22 species). The poor composition of species in 2007 and in 2011 was mainly caused by non-performance of spring surveys.

One of the representative parameters of fish species occurrence in the water area is the frequency of occurrence at sampling points shown as a percentage of the total number of samples taken (Annex 7, Table A1). The absolute leader in terms of adapting to the North-East Caspian Sea water area is roach. From year to year, roach frequency of occurrence was at least 92%-100% of the monitoring stations. Bream frequency of occurrence was also quite high (70% to 92%). Regular high frequency of occurrence (between 44% and 75%) during all 11 years (2006–2016) attributes to the saposchnikowii and Agrakhan shad. A more interesting were changes in frequency of occurrence of other fish species. The report on 2006–2010 monitoring findings [Environmental Monitoring Reports, 2006–2010] mentioned a potential trend in decrease of quantitative variables of predatory fish species with a fairly high correlation [Pravdin, 1966]. The trend was entirely confirmed over the next five years. In the period 2011–2016, pike and catfish disappeared from net catches across the entire North-East Caspian Sea area under survey. Predators such as zander and asp significantly reduce their habitat area (Figure 10.1.3). The tendency of marine habitat reduction affected not only predators, but also some other species of fish that inhabit mainly desalted water, such as white-eyed bream and sabre fish, due to general increase of salinity as a result of the sea level changes.

Change of nekton fish species number per one monitoring point over the years is considered as a more troubling sign. This variable decreased gradually within the period 2006–2015. Such changes can be an indication of reduction in species richness in the water area under survey (Figure10.1.4).

Monitoring of long-term changes in spatial and time dynamics in the number of fish species in fixed net catches provides evident confirmation of decline in species diversity in the water area under survey (Figure 10.1.5). The distribution maps clearly show that during the initial period of monitoring surveys in 2006–2008, the number of species in catches was relatively high with biodiversity tending to rise from the south to the north. The highest number of species was

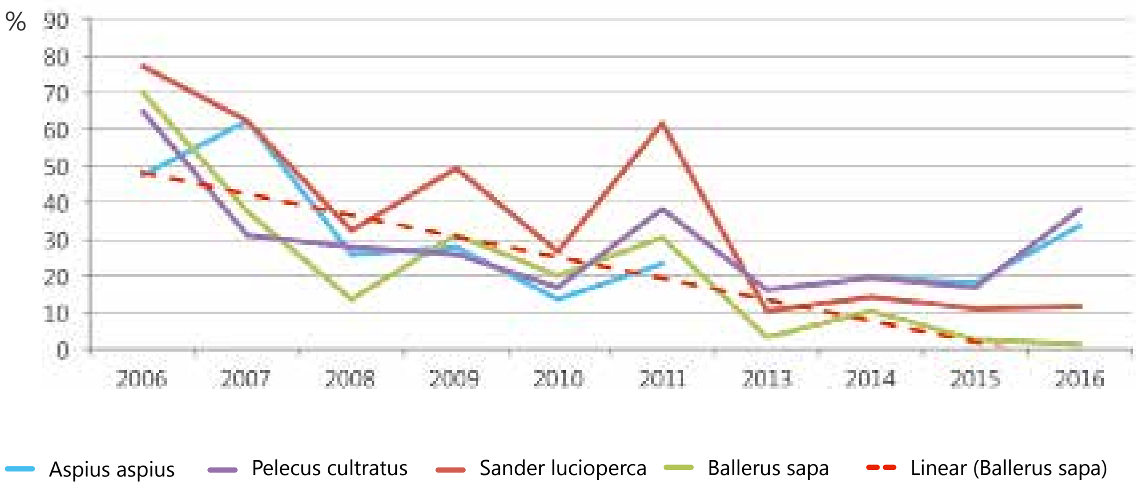


Figure 10.1.3 Dynamics of changes in the frequency of occurrence for certain fish species of the nekton community, by years

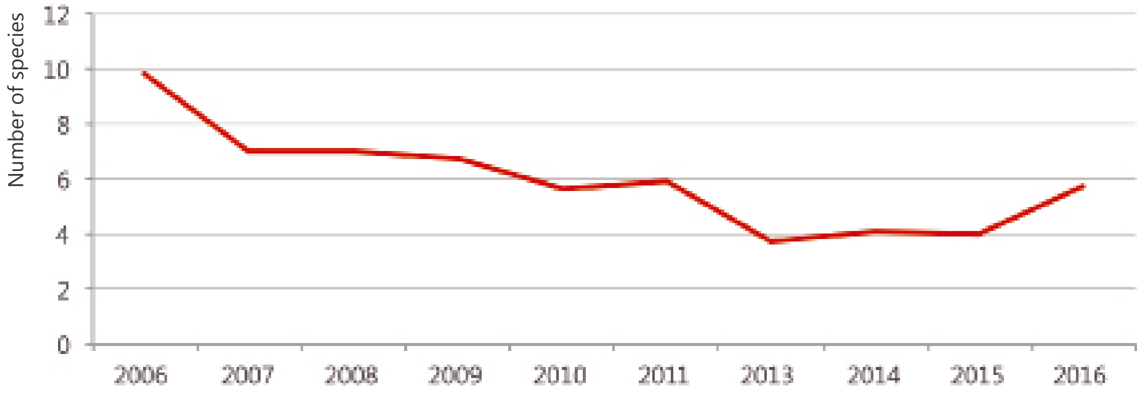


Figure 10.1.4 Dynamics in the number of nekton community fish species per one monitoring point

observed close to the reed zone on the north-east coast, mainly due to freshwater species from the pre-estuary zone of the Zhaiyk River.

However, in 2009–2011 the number of fish species in catches began to reduce significantly across the entire water area under survey. In recent years, the fish species composition in catches reduced even further. A certain level of biodiversity still remains in the coastal reed zone due to freshwater species and within Kalamkas area because of marine species.

The highest frequency of occurrence among the benthopelagic community representatives within the North Caspian Sea water area belonged to the monkey goby, on average 84%, roach — 68%, sand smelt — 59% and Black Sea-Caspian sprat – 46%. Over the years of observations, the frequency of occurrence of benthopelagic fish species fluctuated within the wide range and its regularity depended on the fish species.

The most stable occurrence across the water area was seen for deep-sea fish species, such as roach, sprat and sand smelt. At the same time, roach and sprat have managed to keep their habitat more or less stable for many years, while sand smelt has gradually taken over new territories, expanding their presence in the region (Figure 10.1.6).

The situation with bottom fish is not that satisfactory. The previously common goby species such as longtail dwarf goby, goad goby and Knipowitschia iljini had significantly reduced their habitat by 2010 and are currently observed at a low percentage of monitoring stations (Figure 10.1.7). Even absolute dominant species in the benthopelagic community such as the monkey goby is continuously reducing its presence.

Monitoring of the number of fish species per one monitoring station within a certain water area is a simple and reliable indicator of species abundance. This particular variable for the benthopelagic community in the North Caspian Sea had been falling gradually since 2007. Some stabilization in species abundance had been observed since 2014 with even a slight increase in 2016. The long-term reduction in the species abundance in the water area under survey can be an indicator of the continuous impact of a number of unfavorable factors (Figure 10.1.8).

Over the decade, the average annual fish abundance in fixed gill net catches varied from 476 specimens/effort to 1,013 specimens/effort (Figure 10.1.9). The highest fish abundance in catches was observed in 2006, 2009 and 2016, and the lowest in 2007 and 2013. The catch biomass during the same period changed from 54 kg/ effort to 171 kg/ effort. The highest catch biomass was in 2006, and the lowest in 2015.

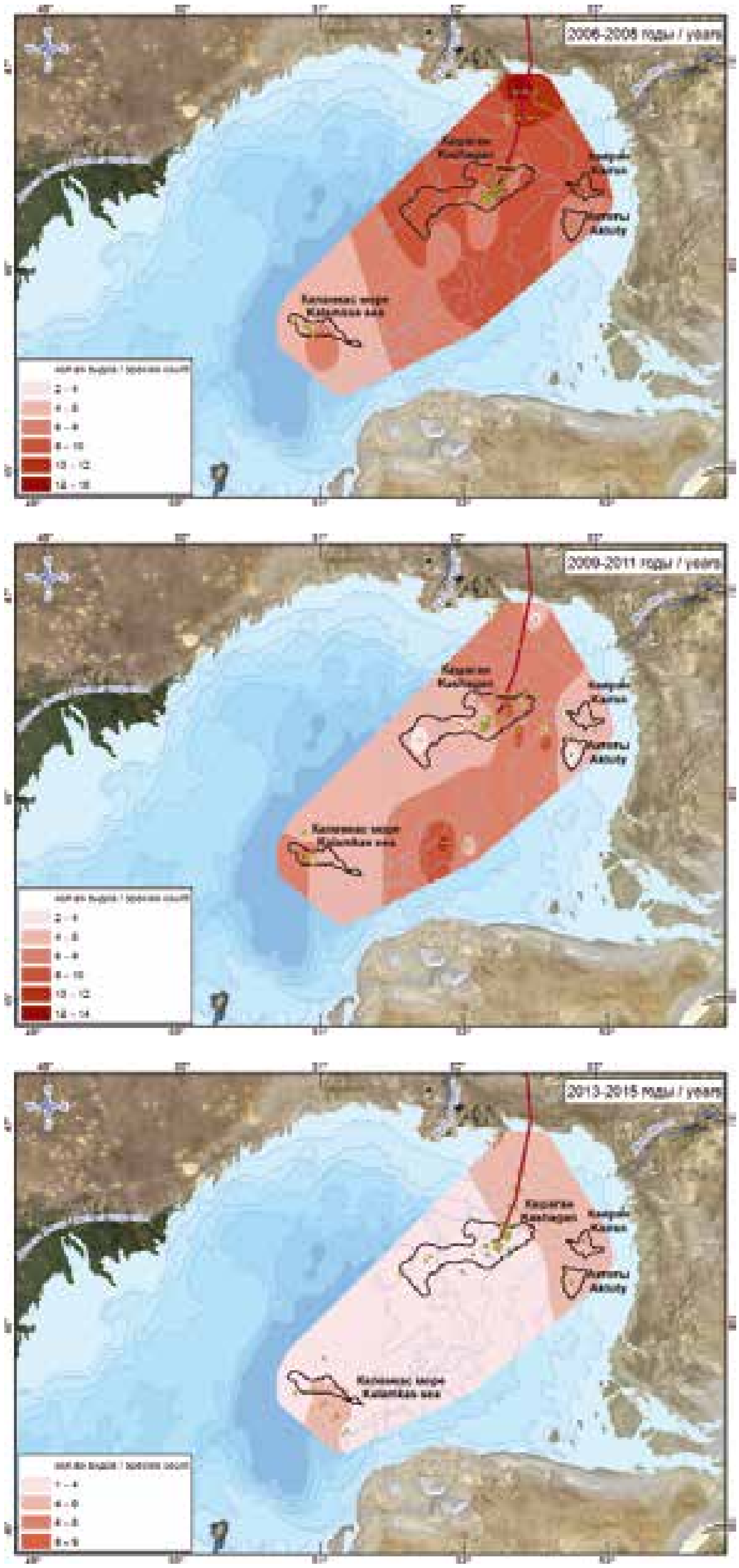


Figure 10.1.5

Spatial and time dynamics in the number of fish species in the nekton community catches

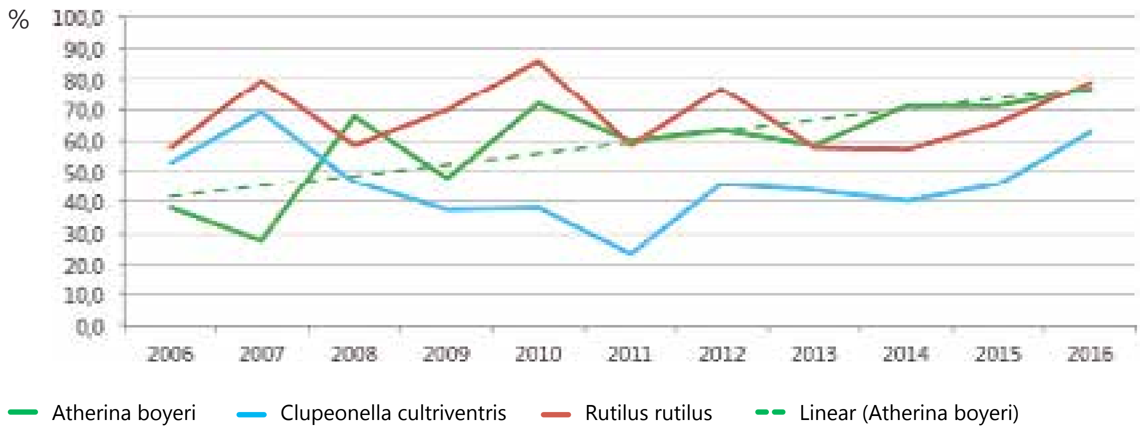


Figure 10.1.6 Dynamics in the frequency of occurrence of certain species of benthopelagic fish community, by years

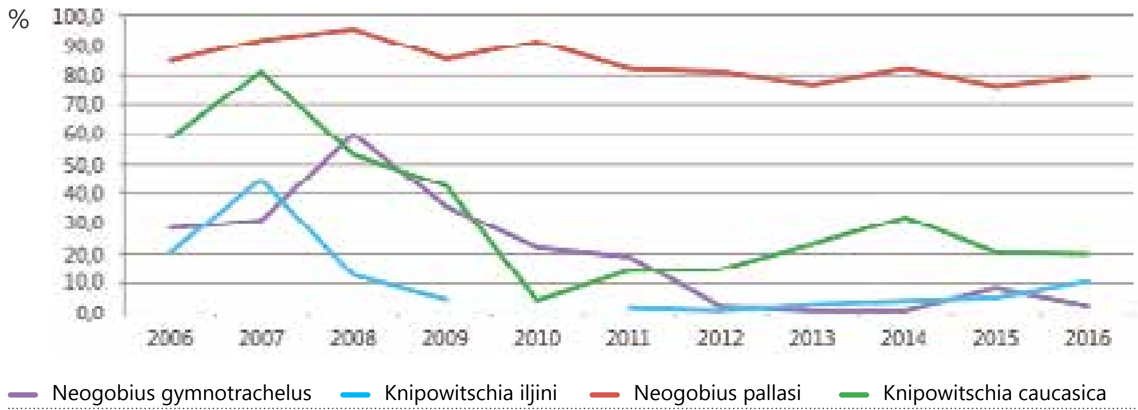


Figure 10.1.7 Dynamics in the frequency of occurrence of goby of benthopelagic community, by years

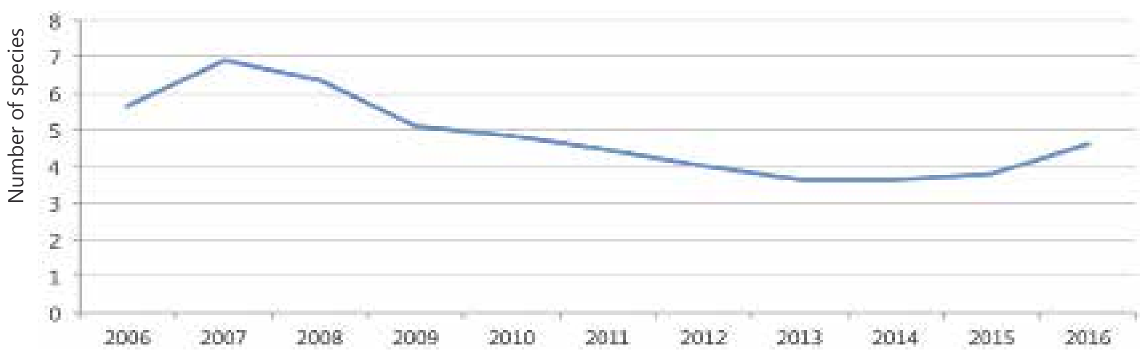


Figure 10.1.8 Dynamics in the number of the benthopelagic community fish species per one monitoring station on average

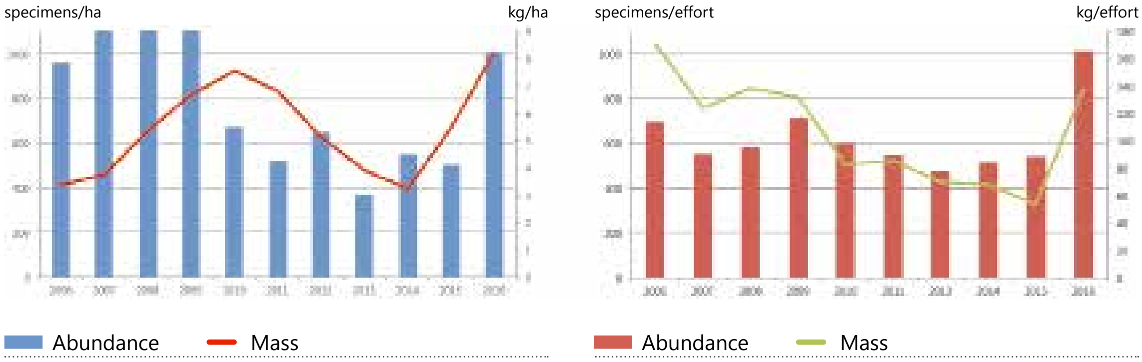


Figure 10.1.9 Dynamics in quantitative variables of the nekton (on the left) and benthopelagic (on the right) fish communities, by years

During the period under review, the average annual fish abundance in bottom beam trawl catches varied from 373 specimens/ha to 1,566 specimens/ha (Figure 10.1.9). The highest fish abundance in catches was observed in 2007, 2008, 2009 and 2016, with the lowest recorded in 2013. Catch biomass for the same period fluctuated in the range of 3.2 kg/ha — 8.2 kg/ha. The highest catch biomass was recorded in 2016 and the lowest in 2014.

The group of dominant fish species in fish communities according to their quantitative variables and frequency of occurrence plays a leading role in relations between community members, such as predator-victim relations, and in competition for feed stock or spawning areas. Therefore, this species group may be treated as the community core where changes determine the structure and dynamics of the entire community. The convenient tool to identify the community core can be the "significance" of species in the community, which is equal to the average percentage of abundance and biomass multiplied by the frequency of occurrence index. As this variable is based on relative quantities, it allows a quite correct comparison of changes in the community core in case of different number of stations or water area coverage.

Analysis of all 2006–2016 net catches based on this variable allows identifying 10 species of fish such as stellate sturgeon and Russian sturgeon, three species of shad — North-Caspian, saposchnikowii and Agrakhan shad, roach, asp, bream, common carp and zander in the nekton community (Figure 10.1.10). These species of fish account for more than 80% of annual catches in abundance and biomass terms. They also formed the core of the nekton community in the period under review. The fish community core is a relatively dynamic structure, and typically it is formed by fish species that prefer certain habitat biotopes and are relatively large in size. Monitoring of changes in qquantitative variables is easy for this type of species group.

A small number of species is dominant in the benthopelagic community in terms of quantitative variables and frequency of occurrence, however, they play a leading role in relations between the community members (Figure 10.1.11).

All bottom beam-trawl catches in 2006–2016 showed the core consisting of the following 8 fish species such as Black Sea-Caspian sprat, roach, bream, sand smelt, monkey goby, goad goby, bighead goby and longtail dwarf goby.

10.1.3 Analysis of the spatial and time changes in the community core

Nekton fish community

Dynamics in fish abundance in the nekton community in the North-East Caspian Sea was determined by the most dominant fish species. The most abundant in net catches across the years of observations was roach, i.e. in the range from 273 specimens/ effort to 437 specimens/effort (Annex 7, Table A3). The next most abundant in net catches was bream, i.e. from 23 specimens/effort to 85 specimens/effort. Agrakhan shad showed low but stable abundance across the years — from 8 specimens/effort to 48 specimens/effort. Saposchnikowii shad abundance fluctuated from 5 specimens/effort in 2011 to 299 specimens/

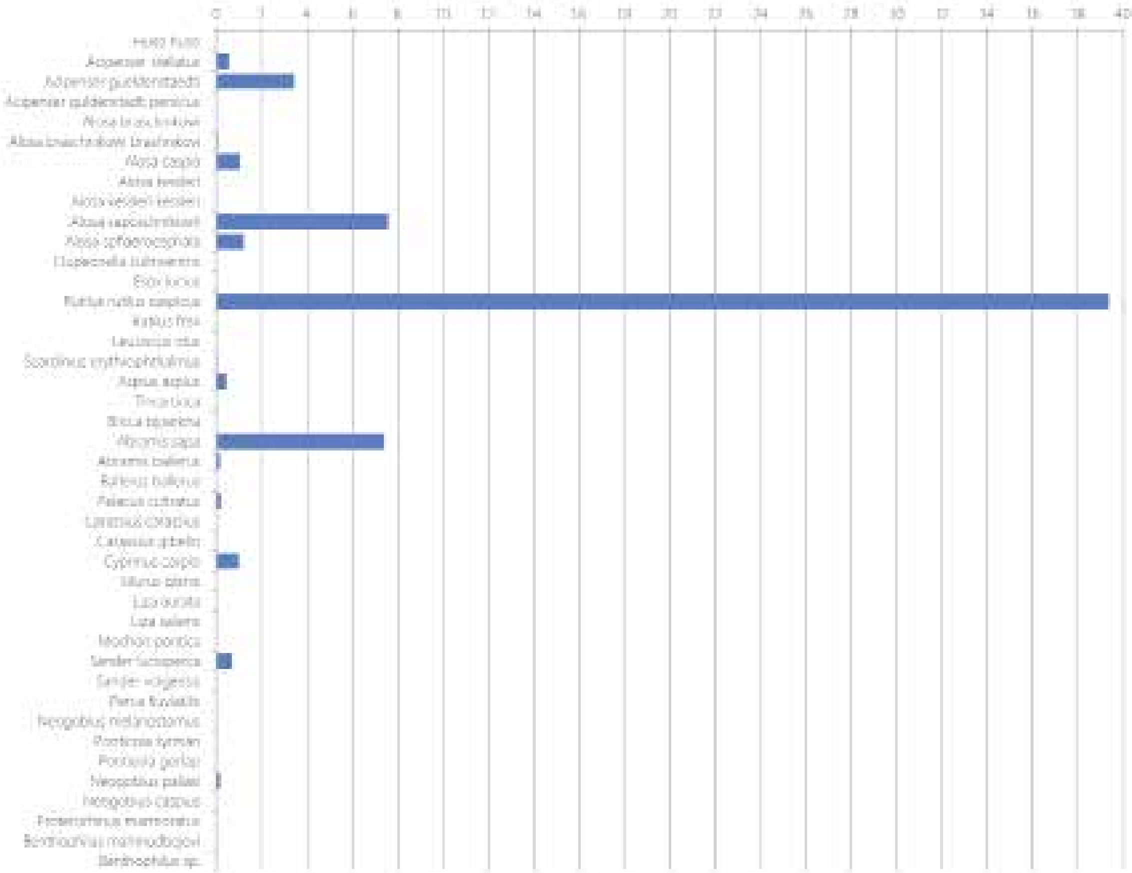


Figure 10.1.10 Significance variables of the nekton community species for 2006–2016

effort in 2016. Abundance “bursts” of some other fish species was observed. In 2016, North Caspian shad abundance was many times higher than long-term variables. In 2006, rudd was caught in large quantities (more than 155 specimens/effort), but 2 years later this species disappeared in the sea water basin.

The long-term dynamics in sturgeon family abundance requires a special mention. The 2006–2010 interpretation report had described a very alarming trend of exponential decrease of Russian sturgeon abundance in standard net catches at all monitoring stations. This trend had a high correlational probability and there was even an

Russian sturgeon *(Acipenser gueldenstaedtii)*

Stellate sturgeon *(Acipenser stellatus)*

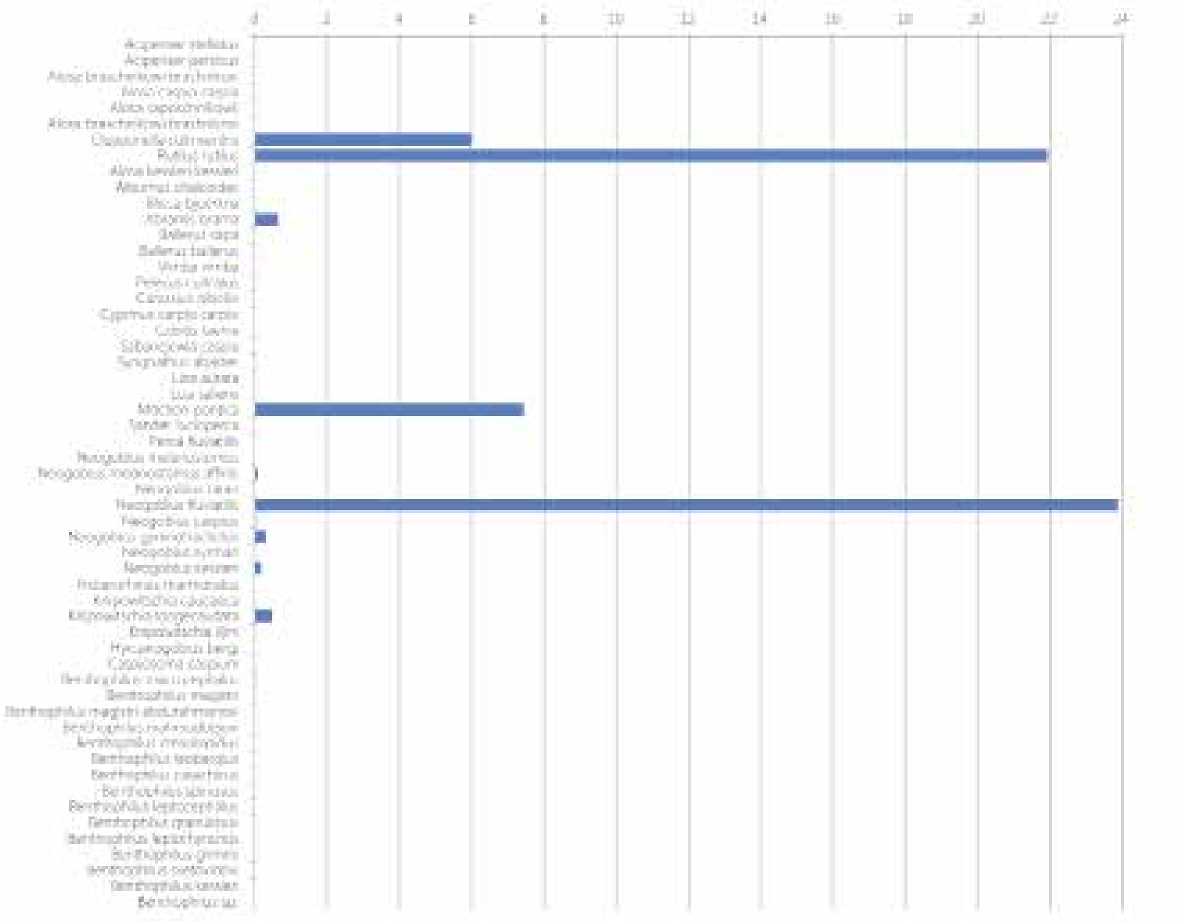


Figure 10.1.11 Significance variables of the benthopelagic community species for 2006–2016

attempt to forecast further development of the process according to the exponential trend line [Monitoring Reports, 2006–2010]. At that time the situation with sturgeon was called catastrophic. Six years later, the forecast unfortunately was confirmed. Figure 10.1.12 demonstrates that the abundance in net catches of the two dominant sturgeon species, i.e. stellate sturgeon and Russian sturgeon, reached their lowest levels in 2014–2015, as forecasted. A slight increase of sturgeon abundance in 2016 can be either an accidental fluctuation and the start of stabilization or restoration, however, it will take at least two years of monitoring surveys to understand the reason.

Changes in abundance of sturgeon in various parts of the water area under survey were also analyzed. If we compare the long-term changes in abundance within the Kashagan East water area, which was exposed to a significant man-caused impact, especially during construction of artificial islands, and changes of abundance at Kalamkas field, which had not yet been affected by active economic activities, then we see a similar tendency to reduction of sturgeon abundance on an annual basis. Dynamics in stellate sturgeon abundance demonstrates very clear similarity despite the fact that the distance between these locations is approximately 120 km. Likewise, 2006–2016 saw a reduction in size variables for Russian sturgeon, i.e. in the proportion of both large and small specimens [Pravdin, 1966]. This can suggest an increased elimination of sturgeon producers, for example, as a result of poaching, which, in its turn, leads to decline in reproduction and reduction in replenishment with fish youngsters.

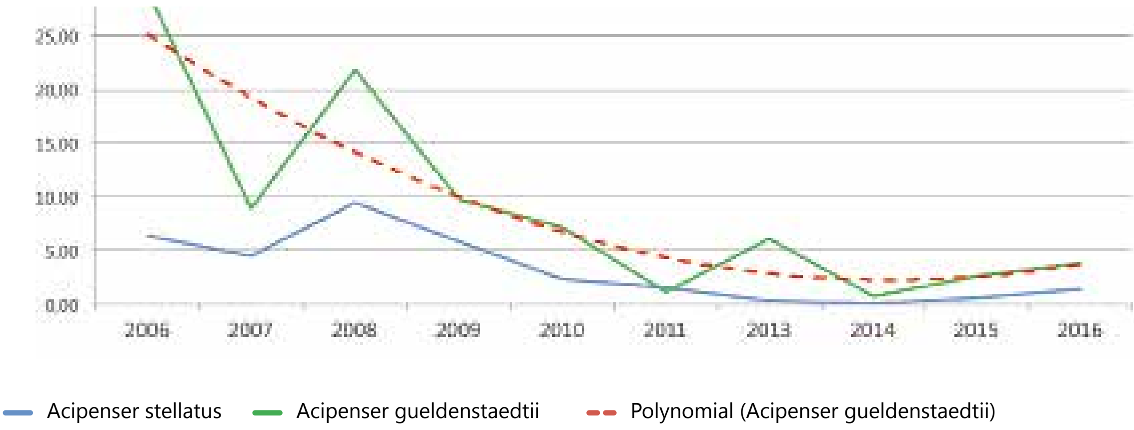


Figure 10.1.12 Actual dynamics in abundance of stellate sturgeon and Russian sturgeon in net catches

These conclusions are well correlated with the spatial and time dynamics in abundance of the most dominant sturgeon species, the Russian sturgeon, during the monitoring surveys of ichthyofauna in the North-East Caspian Sea (Figure 10.1.13).

The highest abundance of sturgeon was observed across the entire water area under survey in 2006–2008. Herewith, the change in its abundance was observed from the southern deep water section in Kalamkas area, to the north-eastern coastal area. In 2009–2011, Russian sturgeon abundance had reduced across the entire water area under survey, gradually extending to the southern deep water part of the North-East Caspian Sea. In recent years, more or less considerable abundance of sturgeon remains only to the south of Kalamkas field. Within all other parts of the water basin only individual sturgeon species were found.

Thus, it can be concluded that operations at the field are not a determining contributor into the catastrophic reduction in abundance of valuable sturgeon species. The main reasons of adverse impact on the populations of these ancient ichthyofauna representatives existed long before the start of offshore development in Kazakhstan Sector of the Caspian Sea. These reasons are well known and include rivers regulation, water environment pollution, overfishing, poaching, etc. Thus, the current situation requires immediate environmental or legal actions.

Some features of the long-term dynamics in abundance of roach, the main dominant species of the nekton community, are of special interest.

Within different areas of monitoring surveys in the North-East Caspian Sea the changes of the roach abundance over the years are specific (Figure 10.1.14).

The dynamics in the roach abundance is the most stable and steady within Kashagan water area. The fluctuations in this species abundance over the years have not been significant and remained within the range of 300-500 specimens/effort per years. The dynamics in the roach abundance within the Oil field pipeline area is less stable and can fluctuate significantly by years. However, the tendency to general increase of the roach abundance is observed within this area. Probably it is related to availability of a large reed zone as a convenient ground for spawning and safekeeping of young fish. At Kalamkas field the roach abundance variables are lower than in other areas under review and moreover, demonstrate a tendency in reduction, possibly due to changes in the sea water salinity. The roach is the most adaptive fish species which easily adapts to any changes in its environment and is quite tolerant to changes in salinity. This enabled wide-spread occurrence of the roach which became the main dominant species of the North Caspian Sea ichthyofauna.

Variance of the roach size and weight characteristics and fattening variables are within average long-term values. At the same time, while body length variables are relatively stable, insignificant decrease of average body length was observed in 2011–2016 as compared to 2006–2010 within Kashagan field area, Oil field pipeline area, and, to a less extent, within Kalamkas area.

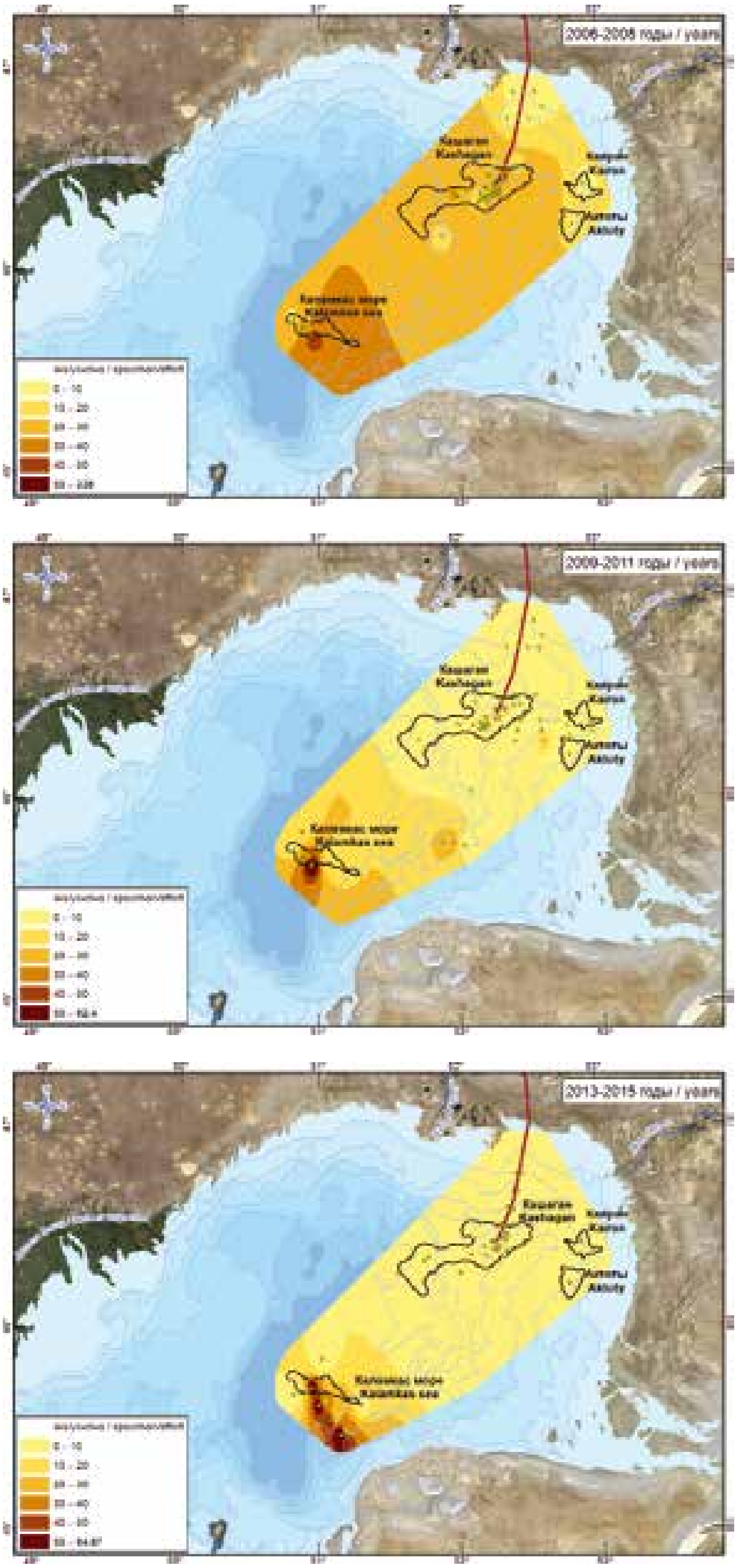


Figure 10.1.13

The spatial and time dynamics in Russian sturgeon abundance during the ichthyofauna monitoring

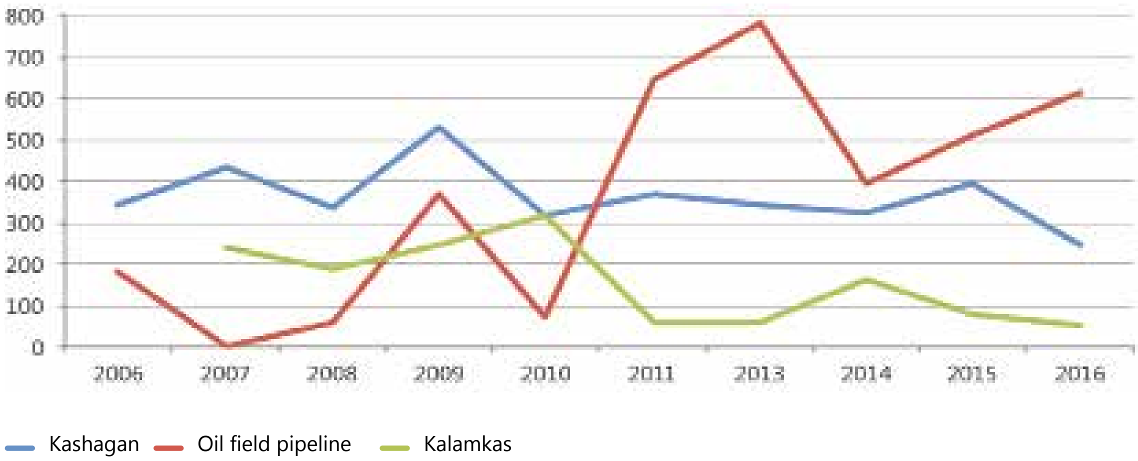


Figure 10.1.14 Dynamics in the roach abundance in the nekton community within various areas of the North-East Caspian Sea

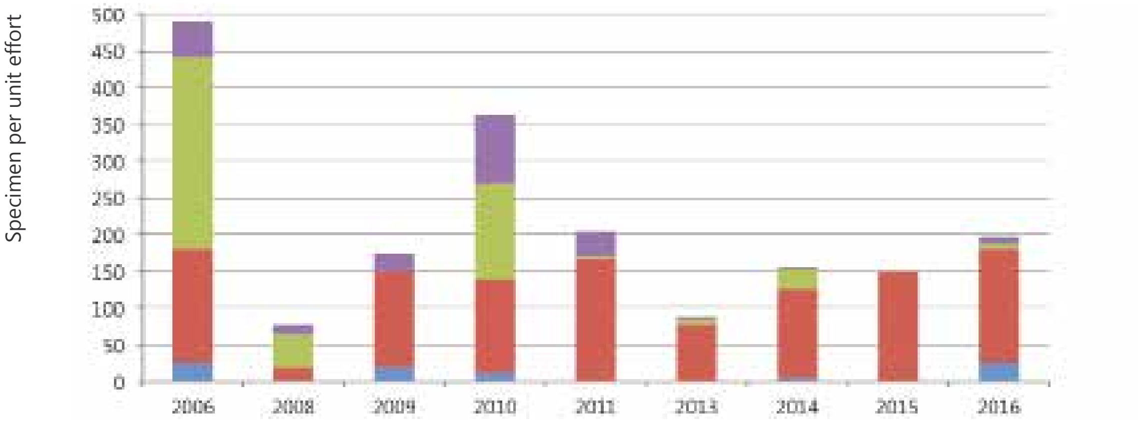
The roach age range in the majority of the areas under survey was 8-12 years and in some years it was up to 14 years. Fish aged 3-5 years forms the basis of all age range structures. Thus, the roach biological variables within all water areas under survey in 2006–2016 serve as the evidence of stable condition of this species population.

Other freshwater fish species are not so labile, which is confirmed by the dynamics in its abundance within the areas under study. In the Oil field pipeline water area closest to the Ural river estuary and the reed zone, the species abundance is high especially in spring (Figure 10.1.15). At the beginning of the monitoring period, common carp and zander were predominant in abundance. Bream was a dominant species and stable component of the nekton community. In Kashagan East water area, the abundance of these representatives in the nekton community core was decreasing significantly, with the common carp practically disappearing from samples. In Kalamkas water area on the borders with the Middle Caspian Sea, the sea salinity is already too high for these species, therefore, out of all fish species under review only bream was found in this area and in limited numbers.

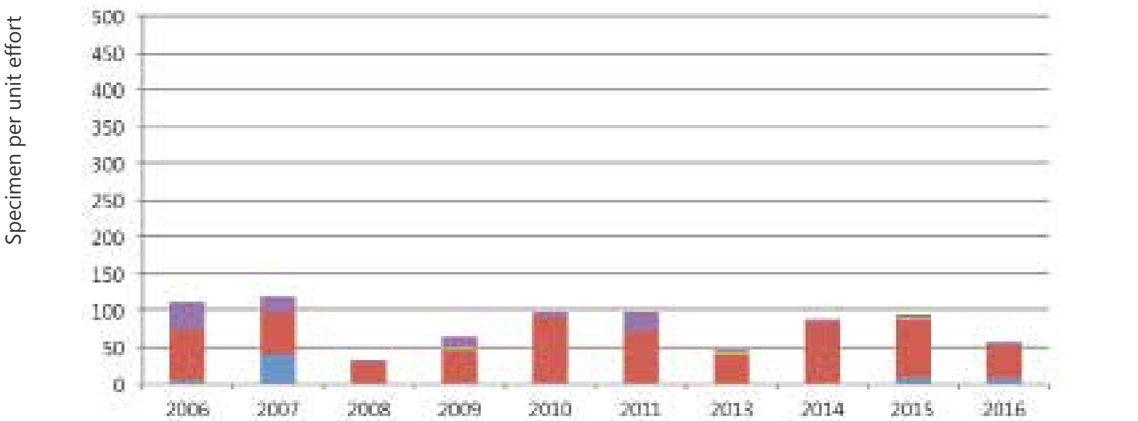
The bream age range is relatively wide, i.e. from 2 up to 12 years, especially within Kashagan East and Oil field pipeline areas. The abundance of 10-12-year-old specimens is not high. The long-term dynamics in the age structure is stable. Slight fluctuations in the maximum age ranges and modal value comply with average long-term values. During all years of surveys in the various areas, 4-6-year-old specimens prevailed in catches. At the same time, the bream average age change was observed in the trunklies area due to increase in fish youngsters' occurrence in catches in 2009 and 2011. A relatively wide age range of the bream serves as evidence of

Rutilus rutilus *(Rutilus rutilus)*

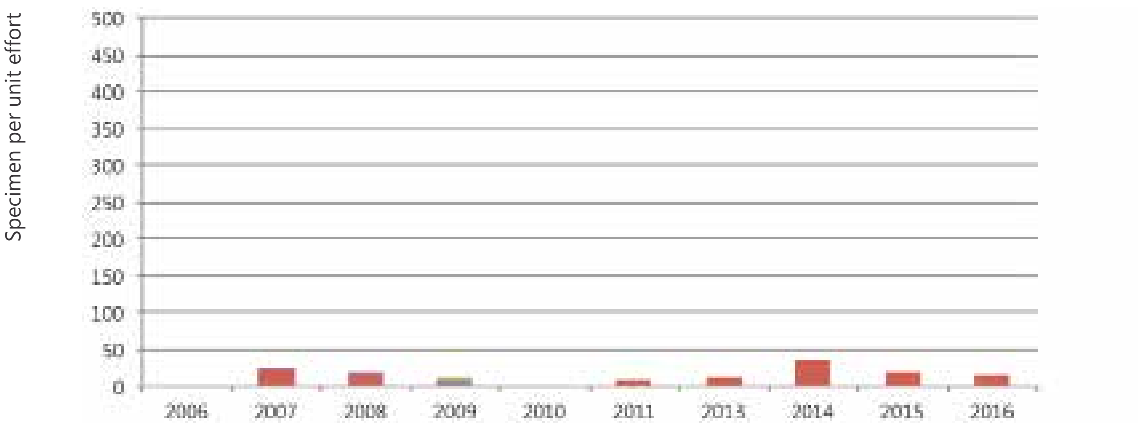
Bream *(Abramis brama)*



OIL FIELD PIPELINE



KASHAGAN



KALAMKAS

Sander lucioperca Cyprinus carpio carpio Bream Aspius aspius

Figure 10.1.15 Dynamics in the abundance of freshwater fish species, the part of the nekton community core, within various areas of the North-East Caspian Sea favorable status of its population during the study period. Review of other biological characteristics of the bream from the various areas also confirms sufficient homogeny in all study areas in various years. Thus, the bream biological parameters in all areas in 2006–2016 are within average long-term values and prove stable condition of this species population.

Benthopelagic fish community

The monkey goby had the highest abundance in bottom beam-trawl catches, i.e. from 138 specimens/ha to 771 specimens/ha (Annex 7, Table A4). The Black Sea-Caspian sprat from 4 specimens/ha to 221 specimens/ha, the roach — from 46 specimens/ha to 199 specimens/ha and the sand smelt — from 6 specimens/ha to 189 specimens/ha are next in the row in terms of the highest abundance. The bream had a small but stable abundance over the years, i.e. from 2 specimens/ha to 13 specimens/ha.

The dynamics in the quantitative variables of the benthopelagic community over the years depended on biology and life pattern of the species comprising it. In the deep sea group of fish in this community, the average abundance over the years fluctuated widely without any visible regularity. These species include the Black Sea-Caspian sprat, the roach, the bream and the sand smelt. The reasons of the fluctuations in the abundance of the benthopelagic community can be the specific nature of the aquatic life environment in the various habitats. The most representative material with respect to benthopelagic community abundance was collected in three areas, i.e. Kashagan East, the Oil field pipeline route and Kalamkas. These three water areas are easy objects for identification of potential impact of regional factors on the hydrobionts abundance. Kashagan East and Kalamkas fields are both located in open waters of the North Caspian Sea, however, at some distance from each other. The Oil field pipeline route is located close to Kashagan East, however, it is considered as a coastal shallow water area with the reed belt and under significant impact of the Zhaiyk river delta.

The roach is one of the dominants in terms of quantitative variables in any fish community of the North Caspian Sea. In the benthopelagic community it is mainly represented by active fish youngsters. The dynamics of changes in the roach abundance at Kashagan East and Kalamkas are almost always the same, even though the distance between these locations is about 120 km, and no operations had been performed at Kalamkas (Figure 10.1.16). This clearly confirms that the 10-year development of Kashagan East had no impact on the roach and the dynamics in its abundance.

The low abundance of roach youngsters within the Oil field pipeline water area can be the result of natural causes and species preferences. Thus, since the beginning of the period under review this location was characterized by complete absence of sturgeon and reduced variables for roach abundance and biomass.

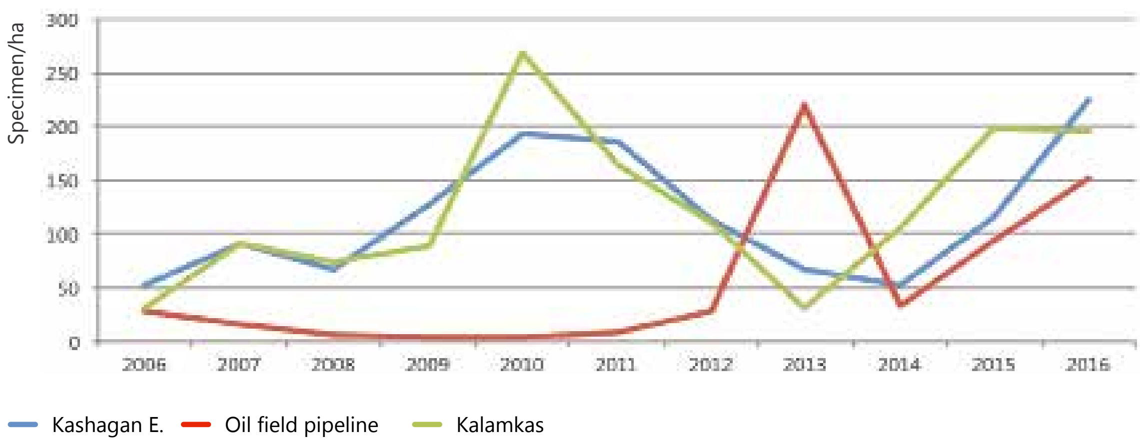
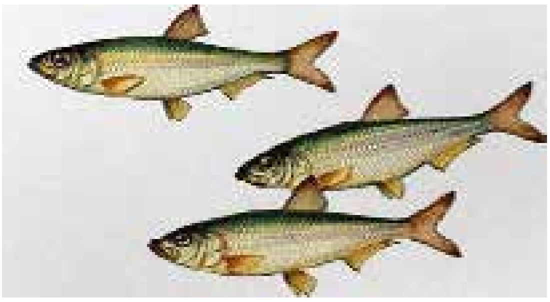


Figure 10.1.16 Dynamics of the roach abundance in the benthopelagic community at various locations in the North-East Caspian Sea

Shad *(Alosa saposchnikowii)*



Sprat *(Clupeonella cultriventris)*

The most mobile representative of the benthopelagic community core was the Black Sea-Caspian sprat from the herring family. It is a marine species and migrates to the North Caspian Sea mainly in spring. The dynamics in the sprat abundance over the years in all monitoring areas had an irregular nature and did not depend on conditions of the water area under survey. In 2006–2016, all surveyed areas were characterized by increase in the average fattening variables of the Black Sea-Caspian sprats according to Fulton that proves improvement of fattening conditions for this species. The range of the biological parameters of the Black Sea-Caspian sprats in all surveyed areas and during all years was within average long-term values, which serve as evidence of the stable condition of its population. The extension of the size range of sprats also confirms improvement of its population conditions. The long-term dynamics in size composition is in line with typical tendencies specific for short-cycle species.

Regularities are traced in the dynamics in abundance of other marine fish species (the sand smelt) in the benthopelagic community core. On average, lower abundance is observed within Oil field pipeline water area in the shallow coastal zone. The highest sand smelt abundance during all years of surveys was recorded in Kashagan East and Kalamkas areas. Furthermore, the sand smelt abundance has tended to grow within all surveyed areas. Over a range of years, changes in average sand smelt size characteristics in various surveyed areas were minor. In 2006–2016, a regular increase of the sand smelt fattening variable according to Fulton was observed within all surveyed areas. This proves improvement of its feed stock in the surveyed areas over the last years. Similar to sprats, the sand smelt does not form isolated populations within the limited habitats. Over the entire 11-year period of surveys, the sand smelt size range has one-peak nature. The minimum modal size of the sand smelt in catches had decreased in 2016 due to significant extension of the size range of the sand smelt that year, which serves as an evidence of healthy population in surveyed areas and sufficient and regular replenishment with fish youngsters. All biological parameters for this species during the observation period in all areas and the wide size range in the sand smelt catches prove stable and steady condition of its population.

The specifics of the long-term dynamics in the bream abundance is quite predictable. Within different parts of the North Caspian Sea water area the bream abundance was relatively stable. Herewith, because of the salinity level, the lowest abundance of this species during all years was

Monkey goby *(Neogobius pallasi)*

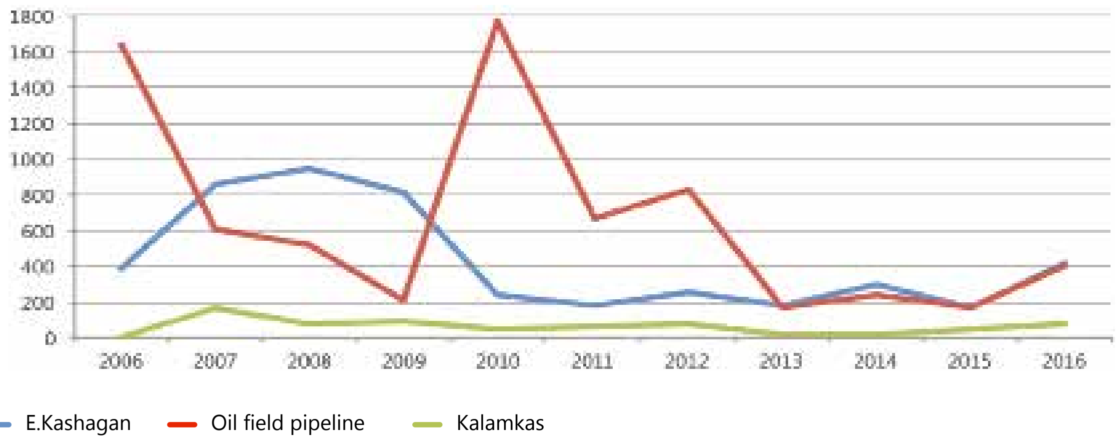


Figure 10.1.17 Dynamics of the monkey goby abundance within various areas of the North-East Caspian Sea

recorded at the Kalamkas field which is the most remote location from the large rivers estuaries. Significantly high abundance was observed at Kashagan East. The stable and highest abundance of bream is specific for the Oil field pipeline coastal water area.

The monkey goby is an absolute leader in abundance of the benthopelagic community. The distribution of the monkey goby abundance across the various parts of the North Caspian Sea clearly shows environmental preferences of this species. The highest abundance of the monkey goby is observed in the shallow and unstable coastal zone of the Oil field pipeline route which is exposed to surges and storm events (Figure 10.1.17). During the first years of the review period, the monkey goby felt comfortable in Kashagan East water area where its abundance exceeded 800 specimens/ha, and only after 2010 it reduced and stabilized at the level of 200 specimens/ha. As for Kalamkas field, where the water is 10 m deep, clear and has a higher salinity level, the monkey goby abundance is at its lowest, and absolutely free from year to year fluctuations. This is maybe why the species is called the "sandpiper". Due to its environmental preferences, it is quite realistic to assume that significant increase in the monkey goby abundance can be related to large scale changes in turbidity and granulometric composition of bottom sediments (transformation of muddy soil into sand). Increase of the monkey goby abundance at Kashagan East in 2006–2009 can be caused by construction and expansion of islands and construction of Oil field pipeline. Within the Oil field pipeline water area the high abundance variables of the monkey goby can be the consequence of pipelines construction.

It appears that the closest species to the monkey goby in terms of biology and choice of habitat is another representative of the benthopelagic community core, i.e. the longtail dwarf goby. This species also prefers the Oil field pipeline water area, and extremely rarely can be found in other open water area.

On the contrary, the goad goby and the bighead goby, even though they are full members of the goby family, prefer habitats with deep, clean and salt water. Their highest abundance was recorded in Kalamkas water area. Significantly lower abundance was observed at Kashagan East. The goad goby was practically not found in the Oil field pipeline route area during the entire period of surveys.

Such distribution of preferences for environmental niches and habitats within one family can be an evolutionary adaptation for weakening the interspecies competition and for a more efficient territory development.

10.1.4 Recommendations for impact mitigation

The analysis of ichthyofauna condition based on outcomes of 2006–2016 monitoring within the surveyed North-East Caspian Sea water areas clearly demonstrates that the structure, biodiversity, quantitative and biological parameters of fish are quite variable over the years and depend on a number of biotic and abiotic factors. Therefore, the maximum reduction of adverse impact factors arising as a result of human economic activities is vital. At the present stage of science and technology development there are no such production, transportation and oil refining technologies that have no adverse impact on the environment [Ivanov, 2000]. Efficient nature use is a compromise solution between a need in economic activities and conservation of the environment. Environmental damage caused by construction and operation of offshore facilities to produce and transport oil means the losses of environment due its pollution, depletion and destruction [Patin, 1997]. The main impact on ichthyofauna caused by construction and operation of offshore facilities is as follows:

- Disturbance of the sea bed and bottom sediments
- Water intake
- Physical factors (noise and light)
- Physical presence of excavated soil
- Potential release of industrial waste into biota
- Emergency situations.

ONE OF THE MAIN ENVIRONMENTAL REQUIREMENTS IS PERFORMANCE OF CONSTRUCTION ACTIVITIES IN THE SEASONS WHEN SUCH PERFORMANCE IS PERMITTED IN THE SPECIAL ENVIRONMENTAL REQUIREMENTS ZONE.

This requirement shall be taken as the basis for planning of any offshore construction activities and complied with during their performance. In order to mitigate negative consequences on habitat, construction of offshore structures and pipelines shall envisage the following:

- Use of optimum working area space for construction activities
- Minimize tranche width
- Decrease the width of soil dumping areas
- Decrease the distance between pipelines
- Trenching in the coastal zone in winter during the ice period allowing soil dumping on the ice and avoid soil dumping on the sea bed.

All vessels involved in offshore operations shall strictly comply with the following basic requirements to minimize water environment pollution and adverse impact on marine biota:

- Vessels shall follow the established transit corridors
- Ensure vessels bypass of vulnerable locations and minimize the areas of impact by moving vessels.

In order to mitigate impact on fish during sea water intake the following requirements shall be met:

- Sea water intake systems shall be equipped with the relevant fish protection devices, while water intake pipes should be equipped with protective filter-net to prevent juvenile fish, adult fish and other marine organisms entering the units and water intake systems.
-
- Water intake devices shall be installed at the optimal depth in accordance with Maritime Register requirements.
-
- Efficient sea water intake mode (depth and speed) shall be applied.
-
- Efficient water use and subsequent reduction of volumes of sea water intake for process needs.
- Water discharges from vessels cooling and desalination systems shall be performed in compliance with the requirements of effective regulation in the Republic of Kazakhstan.

In order to minimize a probability of introduced species' occurrence in the Caspian Sea the following shall be envisaged:

- Mandatory change of ballast water at treatment facilities in Astrakhan (in case of cargo delivery via the Volga-Don and Volga-Baltic Canals)
-
- Antifouling coating on barges and vessels bottom.

In order to mitigate physical effects on fish the following shall be envisaged:

- Use of construction and process

equipment with the noise or vibration level not exceeding the standard noise and vibration level specified for each type of equipment
- Routine maintenance and operation of process equipment in accordance with manufacturer standards
- Support vessels movement along certain routes (corridors) bypassing the most environmentally sensitive areas, if possible.

The following main waste management principles shall be applied:

- Prohibition of waste discharge into the water to prevent sea water pollution
- Correct identification and definition of all waste to ensure appropriate disposal. Unspecified waste will be subject to analysis to establish the appropriate disposal method.
- Separation of all hazardous waste from other wastes. Incompatible hazardous waste shall not be mixed.
- Waste storage in specially designed containers and appropriate labeling. Waste containers shall be stored in the areas where the appropriate measures for their correct storage are in place.
- Special locations for waste collection during construction activities
- Waste transportation by properly equipped vehicles. Transportation of liquid and solid waste in sealed containers to minimize its potential release to the environment.
- Transportation of waste to landfill/location authorized to accept specific waste types
- Regular leak inspections to minimize a potential leakage of pollutants and hazardous materials into the sea; and utilization of oil retention equipment to mitigate consequences of oil spill.
- Immediate emergency response to mitigate incidents consequences.

The above recommendations have been developed by NCOC N.V. (and its predecessors) for offshore facilities construction and operation. The Company strictly complies with these rules and meets all the above requirements.

COMPLIANCE WITH THE DEVELOPED ENVIRONMENTAL MEASURES IN FUTURE WILL ENSURE SIGNIFICANT MITIGATION OF IMPACT FROM CONSTRUCTION ACTIVITIES, OFFSHORE FACILITIES OPERATION AND OIL TRANSPORTATION ON THE MARINE ENVIRONMENT.

Results of fishery surveys 10.2

In 2007 – 2016, within the framework of fishery surveys performed by the Forestry and Fauna Committee under the Ministry of Agriculture and surveys performed by Atyrau Oblast Department for Natural Resources and Nature Management, the surveys were undertaken to protect biodiversity and identify commercial fish reserves in Kazakhstan Sector of the Caspian Sea [Comprehensive surveys..., 2008–2016].

Such surveys were aimed at:

- Analyzing the changes of hydrological and hydrochemical conditions in the Caspian Sea
- Analyzing the changes in the structure of commercial fish populations and basic biological fish parameters
- Analyzing the composition of commercial ichthyofauna and its distribution in fishery regions
- Analyzing fishing conditions in the area under survey based on annual assessments of the state of fish reserves and other marine animals, and the commercial fishing data
- Calculating maximum permissible fishing limits for commercial fish inhabiting Kazakhstan Sector of the Caspian Sea
- Developing recommendations for rational fishing in Kazakhstan Sector of the Caspian Sea.

Materials and methodology

All surveys were performed in accordance with the *Methodology for Recording Abundance and Calculating the Maximum Pe*rmissible Catch of Fish and Other Marine Animals [Order № 284 dated 4 July 2017 of the Vice Prime Minister of the Republic of Kazakhstan, Minister of Agriculture of the Republic of Kazakhstan.

Pursuant to this Methodology net and trawl catches were performed in accordance with fishing grids in Kazakhstan Sector of the Caspian Sea. Starting from 2013, hydro-acoustic study was conducted in parallel to the fishery study in summer and autumn. Hydro-acoustic study made use of modern scientific echo sounders with inbuilt analytical modules storing all recorded data. The mathematical processing of the data received from a scientific fish catch and a hydro-acoustic study was performed in laboratory conditions. As a result, the data on fish abundance was received and the density of fish distribution (specimens/ha) was identified for the surveyed water area and during the review periods.

10.2.1 Survey outcomes

The survey performed in 2007–2015 established the species composition of commercial ichthyofauna in summer and autumn periods in Kazakhstan Sector of the Caspian Sea represented by 27 species: 4 species of sturgeon (Russian and Persian sturgeon, Stellate sturgeon, and beluga), 5 species of herring (Black Sea-Caspian sprat, anchovies; saposchnikowii, Caspian and Agrakhan shad); 10 species of carp (roach, bream, white-eyed bream, vimba, blue bream, flat bream, sabre fish, common carp, crucian carp and asp), perch (zander and perch) 1 species of catfish (catfish), and 2 species of mullet (golden mullet and grey mullet), Table 10.2.1. Scientific study catches also included low-value ichthyofauna represented by the following families: 10 species of goby, 1 species of sand smelt and 1 species of pipefish.

Scientific study of catches and hydro-acoustic surveys established a non-uniform distribution of ichthyofauna in Kazakhstan Sector of the Caspian Sea. The baseline species in the Caspian Sea are roach and bream recorded with 90–100% frequency of occurrence; sabre fish, asp and herring — 25–30% of occurrence, with all remaining species observed less often — 2–15% in Kazakhstan Sector of the Caspian Sea. The seasonal distribution of fish is shown in Figures 10.2.1 and 10.2.2.

Fish density is higher in the summer months, reaching 300–504 specimens/ha in the north-west region (Issatay) and in the west, which is impacted by the Volga river inflow, and in the eastern and south-eastern parts (Kalamkas and Karazhanbas areas) of the surveyed water area (Figure 10.2.1). Species diversity in these regions is represented by 5–9 species of commercial fish: roach, bream, common carp, crucian carp, sabre fish, asp, catfish, zander and mullet. The dominant species are roach and bream, while the other species are sub-dominant to various degrees.

Low distribution of fish density (23–100 specimens/ha) included occurrence of 2–4 commercial species with roach and bream as the dominant species. Herring, sprats, asp, sabre fish and catfish were encountered less often.

The sites with medium density of 100-300 specimens/ha of commercial fish cover a significant area, approximately 80% of Kazakhstan Sector of the Caspian Sea. The catches included 3–6 species of fish. Roach and bream dominated, while herring, sturgeon and other carp species were subdominant.

The frequency of sturgeon occurrence (according to summer data in 2013–2015) was 2–10% of the surveyed water area, and was represented by Russian and Persian sturgeon and Stellate sturgeon, whose estimated density was in the range of 1–5 specimens/ha. Sturgeon abundance in summer was high for Russian and Persian sturgeon with 3–5 specimens/ha (fishing squares 88, 145 and 169), and for Stellate sturgeon up to 3 specimens/ha (fishing square 219).

In autumn, the migration processes (feeding, pre-spawning and wintering) had impact on the distribution of commercial fish, with total abundance of 300–699 specimens/ha concentrated in the western, north-western and northern areas (Figure 10.2.2).

Similar to summer, the autumn distribution density of fish is mosaic. High abundance of 300–699 specimens/ha is noted in the north-western area of the water basis under study from the Kigach tributary towards Zhambai village, accounting roughly for 21% of the surveyed area. An average abundance of fish of 100–300 specimens/ha was registered at 66% of Kazakhstan Sector of the Caspian Sea water basin. The lowest density of fish was recorded at 13% level of the surveyed

Table 10.2-1 Species composition of commercial ichthyofauna in Kazakhstan Sector of the Caspian Sea

Fish species	Year							
	2007	2008	2010	2011	2012	2013	2014	2015
Beluga — Huso huso	+	+	+	+	+	+	+	+
Russian sturgeon — Acipenser gueldenstaedtii	+	+	+	+	+	+		+
Persian sturgeon — Acipenser persicus				+	+	+	+	+
Stellate sturgeon — Acipenser stellatus	+	+	+	+	+	+	+	+
Caspian-Black Sea shad, Caspian shad — Alosa caspia	+	+	+	+	+	+	+	+
Saposchnikowii shad — Alosa saposchnikowii	+	+	+	+	+	+	+	+
Agrakhan shad — Alosa sphaerocephala	+	+	+	+	+	+	+	+
Black Sea-Caspian sprat, sprats — Clupeonella cultriventris	+	+	+	+	+	+	+	+
Anchovy sprat — Clupeonella engrauliformis	+	+	+	+	+	+	+	
Northern pike — Esox lucius		+		+	+	+	+	+
Roach — Rutilus	+	+	+	+	+	+	+	+
Black Sea roach — Rutilus frisii kutum						+		
Rudd — Scardinius erythrophthalmus				+	+	+	+	+
Common asp — Aspius	+	+	+	+	+	+	+	+
Tench — Tinca				+	+	+	+	+
Flat bream — Blicca bjoerkna			+	+	+	+	+	+
Bream — Abramis brama	+	+	+	+	+	+	+	+
White-eyed bream — Abramis sapa	+	+	+	+	+	+	+	+
Blue bream — Abramis ballerus	+	+		+	+	+	+	+
Sabre fish — Pelecus cultratus	+	+		+	+	+	+	+
Golden or common crucian carp — Carassius				+	+	+	+	+
European common carp (carp) — Cyprinus carpio	+	+	+	+	+	+	+	+
Common catfish — Silurus glanis	+	+	+	+	+	+	+	+
Common zander — Stizostedion lucioperca	+	+	+	+	+	+	+	+
Perch — Perca fluviatilis				+	+	+	+	+
Golden grey mullet — Liza aurata	+	+	+	+	+	+	+	+
Leaping grey mullet — Liza saliens						+	+	+
Total species	18	19	17	25	25	27	25	25

area in Kazakhstan Sector of the Caspian Sea.

Fish abundance in the north-western, western and north-eastern areas of Kazakhstan Sector of the Caspian Sea (surveyed water area) increased due to the relocation of ichthyofauna into it from central and south-western sites, and the downstream migration of fish and juveniles from the estuaries of the Zhaiyk and Volga rivers and their pre-estuary areas. The dominant species in abundance were roach and bream, while sub-dominant species included the Black Sea-Caspian sprat and herring. The value of other commercial fish was lower.

In autumn, commercial ichthyofauna density double decreased to 164–205 specimens/ha in Kalamkas and Karazhanbas areas, due to migration processes. The relocation of commercial fish populations was noted in the north-western and eastern directions.

Thus, commercial fish abundance increased in autumn due to the downstream migration of young commercial fish from coastal regions with extensive overgrowing of high water plants (including the extensive reed belt and pre-estuary sea-coastal areas of the Zhaiyk and Volga Rivers), which reached 43–68% of total abundance in

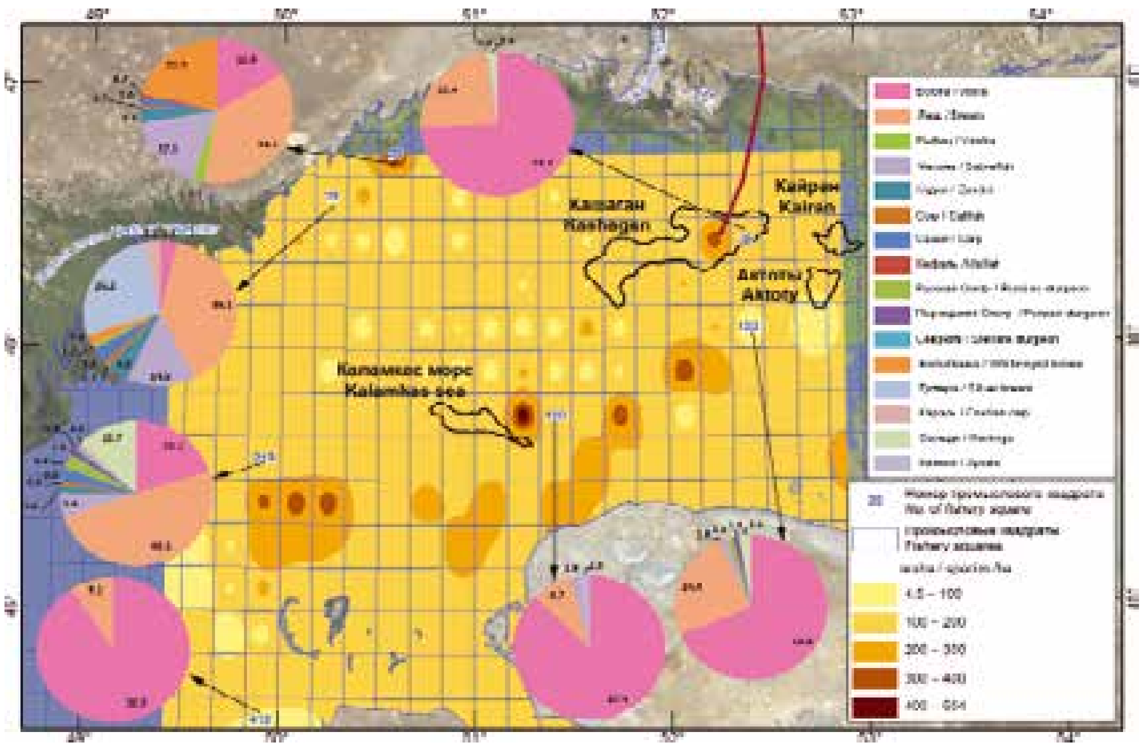


Figure 10.2.1 Density of the summer distribution of commercial ichthyofauna in 2013–2015

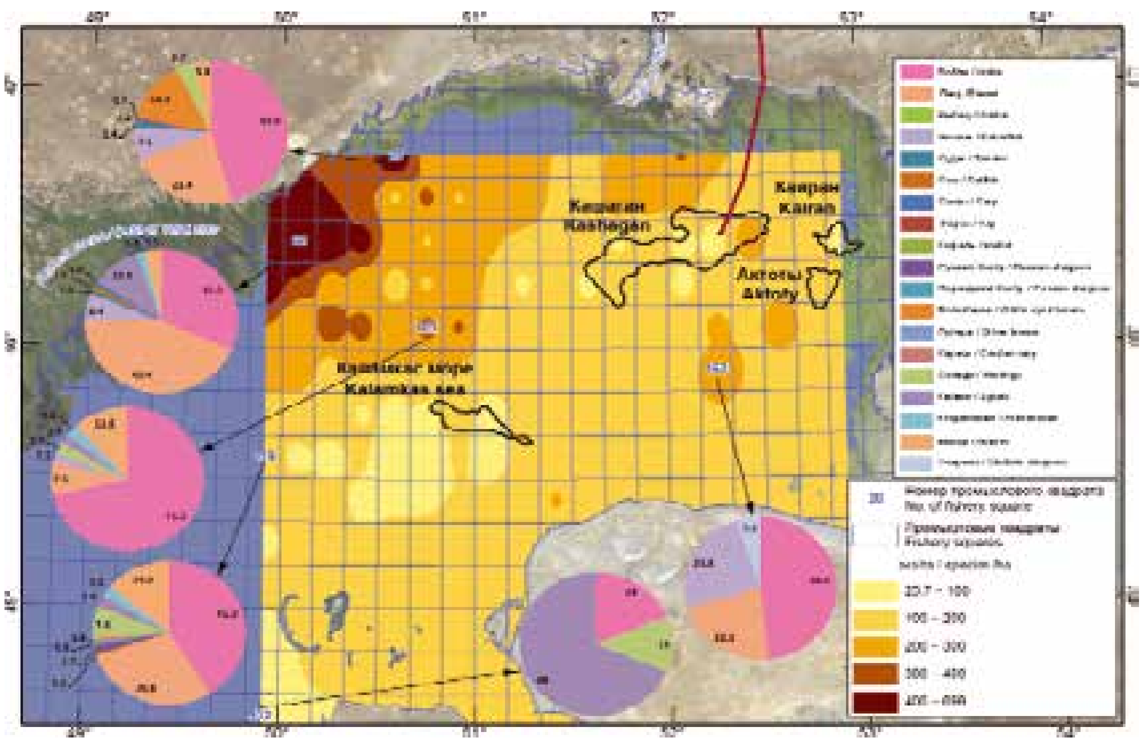


Figure 10.2.2 Density of the distribution of commercial ichthyofauna in autumn 2013–2015

high density areas. In the low and medium density areas, the value of juvenile commercial fish was not high, reaching 12–26%, respectively.

Low-value ichthyofauna is represented in autumn by species from the goby and sand smelt families. Goby family representatives were found at 77% of the surveyed water area with density in the range 1–208 specimens/ha, sand smelt — at 69% with density in the range 1–15 specimens/ha.

In 2013, a specialized hydro-acoustic study was performed in the Caspian Sea as a part of environment protection surveys to research the impact of vessels propellers along the vessel routes on ichthyofauna and the behavior of fish with approaching vessels [KAPE, 2013]. The study showed that with increase of water turbidity, the number of fish staying under the vessel hulls grows. As water transparency decreases from 150 cm to 30 cm, the percentage of fish staying under vessel hulls increases from 2% to 36% of the total fish abundance in the surveyed area and can be exposed to the impact of propellers. Low water transparency means that ichthyofauna is unable to spot moving objects in good time and leave the zone of adverse impact. High turbidity created by fine particles can cause the reflection of a sound wave coming from a moving vessel, which makes it difficult to identify its source and direction.

Results of fishery surveys performed in 2013–2015 and analysis of KAPE file data on scientific and research catches for 2007–2012 were used to create a map of migration routes for sturgeon, herring, sprats and semi-migratory fish. The study showed that the majority of fish during spawning and feeding migration move along the eastern and western coast of the mid-Caspian Sea to 100 m depth. In the water area of the North Caspian Sea, herring moves along the western and eastern coast, Black Sea-Caspian sprats move along the eastern coast to the west, semi-migratory fish and sturgeon move in different directions — to the west into the Volga River delta, including the Kigach channel, and through the central section (Ural valley) and the eastern coast to the Zhaiyk River delta (Figure 10.2.3.).

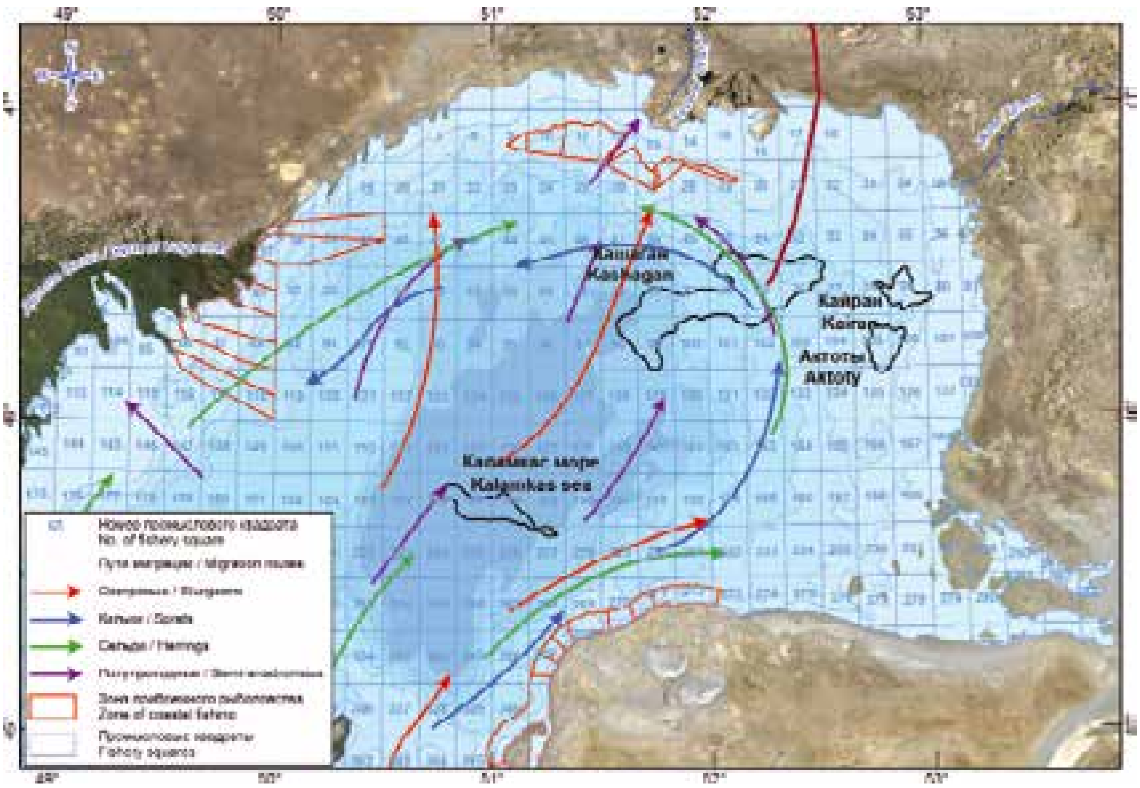


Figure 10.2.3 Map of the migration routes of commercial fish in the Caspian Sea water area

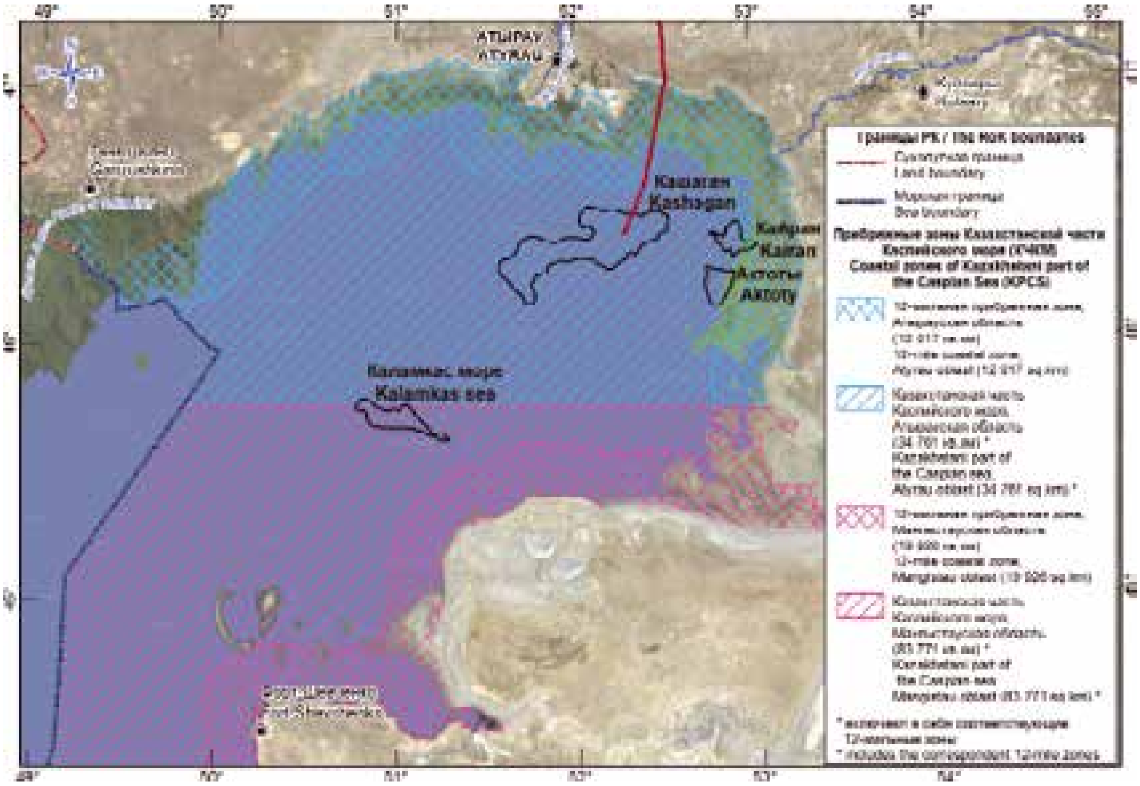


Figure 10.2.4 Distribution of areas in Kazakhstan Sector of the Caspian Sea

10.2.2 Analysis of the commercial fishery in the North-East Caspian Sea

According to the information of the Ural-Caspian Interregional Basin Inspection of Fisheries, development of allocated "marine" fish resources limit takes place at designated sites in the coastal 12-mile area of the Kazakhstan sector of the Caspian Sea (Figure 10.2.4). Maintenance of marine coastal fishing is caused by the fact that nature users apply a fishing fleet with a limited radius of removal from support bases and safe navigation zones. T

he area of Kazakhstan Sector of the Caspian Sea at the level — 27.5 m is 118,045 km^2. The coast line of the Caspian Sea in Kazakhstan is extremely uneven, with the total area of the 12-mile coastal water and the area approximately 31,945 km^2.

The Caspian region has a quite significant number of protected areas, but only 4 of them are located in the Caspian Sea water basin and they are relevant to protection of fish stock and the Caspian seals:

- State nature reserve zone in the northern part of the Caspian Sea (Chapter 1, Figure 1.1.)
- Novin state wildlife reserve zone;
- Ak-Zhaiyk state natural wildlife reserve;
- Aktau-Buzachi state wildlife reserve.

The existence of specially protected nature territories requires approvals of authorized fishery bodies for fishing activities within their water areas, and compliance with environment protection measures in accordance with International Treaties, Kazakhstan Laws and Governmental Resolutions.

According to the data of the Ural-Caspian Oblast Basin Fishery Inspectorate, in 2011–2016, Atyrau Oblast saw a growth in enterprises engaged in fishing, increase of operational capacity, fleet and jobs (Table 10.2-2). The existing fishery fleet allows fishing within the 12-mile zone.

In 2011–2015, there was 23.3% increase in fishery business, which created roughly 650 jobs. 2016 saw a reduction in the fishing fleet to the 2011

Table 10.2-2 Information on fishery enterprises in Atyrau Oblast

	Year					
Parameters	2011	2012	2013	2014	2015	2016
Number of organizations	14	13	15	17	18	19
Number of workers	1536	1838	2190	2210	2190	579
Self-propelled fleet, units	335	416	605	605	600	265
Non-propelled fleet, units	369	409	444	472	494	375
Trammel nets, units	105	199	192	190	192	192
Fingering trawls, units	61	60	56	60	56	56
Fixed nets, units	2400	2552	2792	2795	2848	1843
Trap nets, units	8849	12526	14761	14700	14500	14700
Total catches, tons	4315,63	3757,88	4315,63	3838,13	4067,45	3755,2
Limits reached, %	43,14	33,65	41,16	35,9	38,71	29,34

level and jobs by 957 people.

By 2013, there had been a reduction in commercial fishing gear, with fingering trawls decreasing by 5.6% and trammel nets by 3.65 %. The number of fixed nets and trap nets by 2015 had increased by 15.6% and 39.0%, respectively. Such change in commercial fishing gear was caused by the development of the reed belt water area in 2013–2015. 2016 saw a reduction in commercial fishing gear, jobs and fleet.

According to the Governmental Resolution, fish catch quotas in Kazakhstan Sector of the Caspian Sea are allocated for designated areas in the water basin.

According to the Ural-Caspian Oblast Basin Fishery Inspectorate, annual catches in the designated areas in 2011–2016 amounted to 3.84–4.32 thousand tons, or 33.65–43.14% of the annual quota, Figure 10.2.5.

The official data provided by the Ural-Caspian Oblast Basin Fishery Inspectorate indicated a lower use of catch quotas for herring (sprats, herring and shad) due to their low availability for fishing given the current level of technical capabilities of fishing crews. A specialized fishing fleet, which is currently not available, is needed for a proper and efficient catch of marine fish species.

In case of small fish, catch quotas for commercial fish catches were used at 33.65–43.14% in Kazakhstan Sector of the Caspian Sea. In open

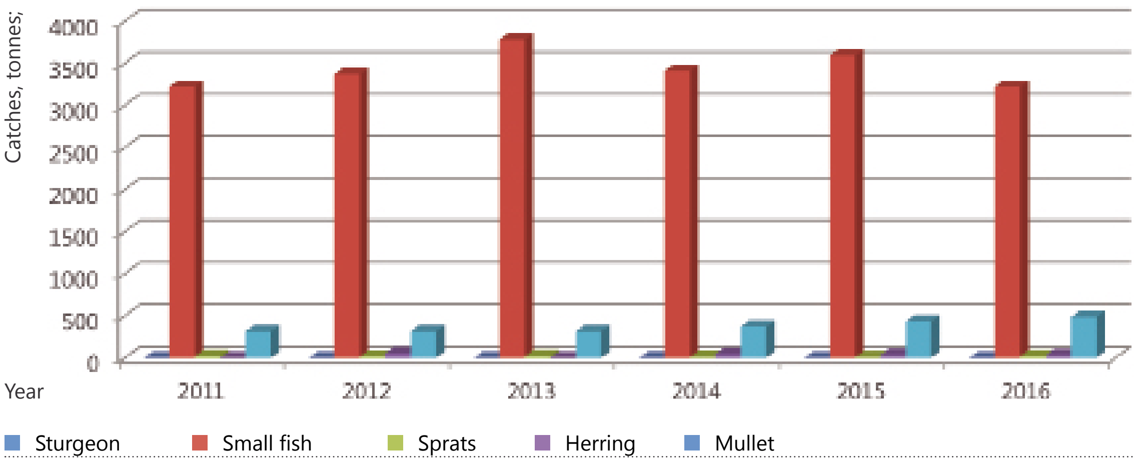


Figure 10.2.5 Details of commercial fish catches in Kazakhstan Sector of the Caspian Sea, 2011–2016

10.3 waters, outside the designated areas there was no catch due to non-availability of a specialized commercial fleet.

Increase of commercial fishing is possible if the commercial fleet is upgraded and fish catch in non-designated areas is conducted and the coastal fishing water area in Kazakhstan Sector of the Caspian Sea is expanded.

Status of sturgeon populations in the North-East Caspian Sea Water Area

The Caspian Sea water area is inhabited by 6 species of sturgeon from 2 orders: beluga (*Huso* (Linnaeus, 1758), Russian sturgeon (*Acipenser guldenstadtii* Brandt, 1833), Persian sturgeon (*A.persicus* Borodin, 1897), Stellate sturgeon (*A.stellatus* Pallas, 1771), barbel sturgeon (*A.nudiventris* Lovetsky, 1828) and sterlet (*A.ruthenus* Linnaeus, 1758). Out of such species, the beluga, Russian and Persian sturgeon, Stellate sturgeon and barbell sturgeon are fattening in the Caspian Sea water area. Sterlet spends its whole life cycle in the river section of the water basin.

Currently, all sturgeon inhabiting the Caspian Sea are included in the Red Book of the International Union for the Protection of Nature in the CR category (critical), which is Annex II to the Convention on International Trade in Endangered Species (CITES).

Previously, sturgeon abundance in the Caspian Sea accounted for more than 80% of the global abundance of sturgeon reserves. Maximum catches in the Caspian Sea have reached 29,000 tons. Currently, given the disastrous sturgeon condition, all Pre-Caspian states have introduced a moratorium on commercial fishing of sturgeon.

The disastrous situation with sturgeon in the Caspian Sea is a consequence of the cumulative impact of a number of factors, such as regulation of river inflow and the subsequent loss of breeding grounds, extreme commercial overfishing (in the last century), sea pollution, the negative impact on the physiological condition of fish organisms and creation of commercial fish reserves. Overfishing in the period from the 1930s to 1980s resulted in reduction of total sturgeon abundance to today's levels and a tendency of abundance drop with development of negative events in their populations.

The need in updated data on modern condition of sturgeon population was determined by increase in man-caused impacts on sturgeon habitat and reduction in fish abundance. Below is the assessment of the current condition of sturgeon populations in the North-East Caspian Sea, based on the data on changes in basic population variables [Comprehensive study reports 2008–2016]. These surveys covered the maximum possible water area in Kazakhstan Sector of the Caspian Sea (over 21,000 km² within the North-East Caspian Sea).

The data received during summer trawl-acoustic and net surveys was used for analysis. The main fishing gear used for catch was a 30-foot otter trawl supplemented with fixed gill nets with mesh size in the range of 20–200 mm (20, 30, 40, 50, 60, 70, 80, 90, 100, 150 and 200 mm). The abundance was calculated in accordance with the methodology provided in Appendices to the Guidelines for preparing biological substantiation for use of fish reserves and other species of aquatic animals [Order № 284 dated 4 July 2017 of Vice Prime Minister of the Republic of Kazakhstan, Minister of Agriculture of the Republic of Kazakhstan].

In the period of 2008–2015, the sturgeon catches included the following species: Russian sturgeon (*Acipenser gueldenstaedtii*), Persian sturgeon (*Acipenser persicus*), Stellate sturgeon (*Acipenser stellatus*) and beluga (*Huso huso*).

Beluga was rarely found in catches in the North-East Caspian Sea water area. In the period 2008–2016, 63 specimens of beluga were registered. They all were caught in the coastal shallow water zone close to the Zhaiyk River estuary in 2008.

It is worth noting that an analysis of changes in the condition of beluga population was not possible due to a single nature of catches.

Russian sturgeon. Its natural habitat includes the Black, Azov and Caspian Sea basins. The Zhaiyk River is the habitat for three forms — hiemal, early vernal and late vernal. The proportions of the various forms in spawning population are not equal, with the highest abundance of hiemal form — 63%, vernal abundance — 31%, and late vernal — no more than 6% [Kazancheyev 1981, Fish of Kazakhstan, 1986].

The Russian sturgeon is lithophilous and ammophilous. In Kazakhstan its spawning grounds are located in the Ural River. Apart from the differences when it enters the river and wintering grounds, the sturgeon forms are different in terms of spawning time and temperature. The hiemal sturgeon spawns at a temperature of 9–12˚C, at the distance of 670–1,200 km from the sea. The early vernal form spawns at the temperature in the range of 12–13˚C and 18–19˚C, while the late vernal sturgeon spawns at 18–24˚C at the distance of 320–650 from the sea [Fish of Kazakhstan, 1986].

Sturgeon reaches sexual maturity at 7–8 years of age for males and 9–10 years for females. However, sexual maturity in mass is reached later. The size and weight composition of the Russian sturgeon population is given in Figures 10.3.1–10.3.2, which indicate a narrowing of the range of body length and weight values in catches of the Russian sturgeon. Decrease in the number of specimens with maximum size and weight parameters can mean an increase in mortality rates and it reflects reduction in size and weight ranges, whereas the absence of specimens in 2012–2016 with lowest size and weight parameters means *inter alia* a lack of replenishment during the same time period. This assumption is confirmed by dynamics of the age structure of Russian sturgeon population presented in Figure 10.3.3.

A reduction in the age of fish in catches has been long observed in Russian sturgeon populations in the North-East Caspian Sea, which confirms unfavourable conditions for its population. It is evident from Figure 10.3.4, Russian sturgeon abundance in the North-East Caspian Sea dropped to 412,000 specimens by 2015.

The reduction in the maximum linear and weight parameters of the Russian sturgeon, and maximum ages recorded, together with the continued drop in abundance, confirm the ongoing degradation of Russian sturgeon population.

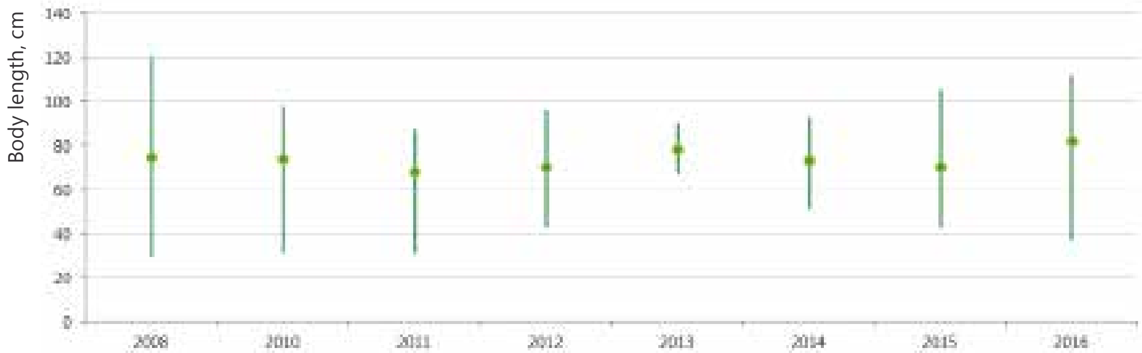


Figure 10.3.1 Size composition of Russian sturgeon in the North-East Caspian Sea water area

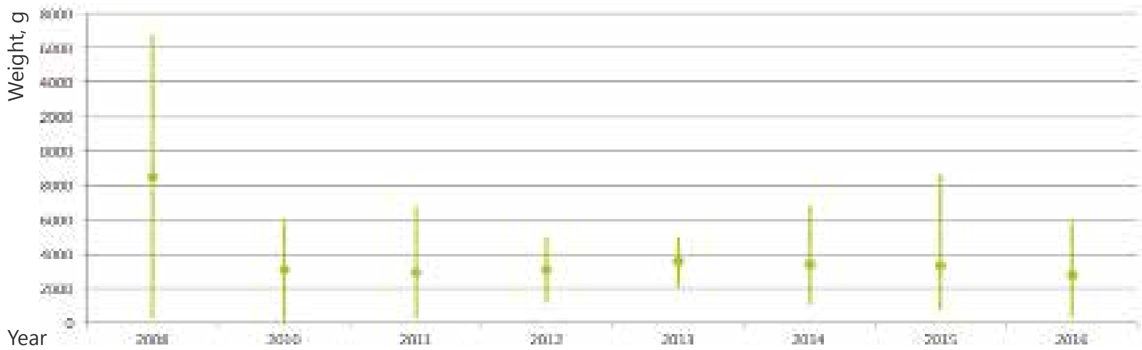


Figure 10.3.2 Weight composition of the Russian sturgeon at the North-East Caspian water area

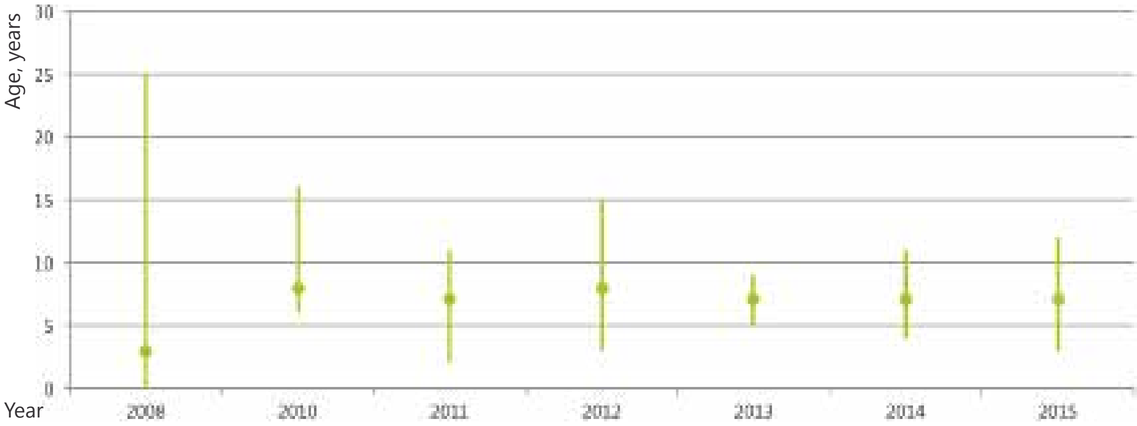


Figure 10.3.3 Change in the age structure of the Russian sturgeon population in the North-East Caspian Sea water area

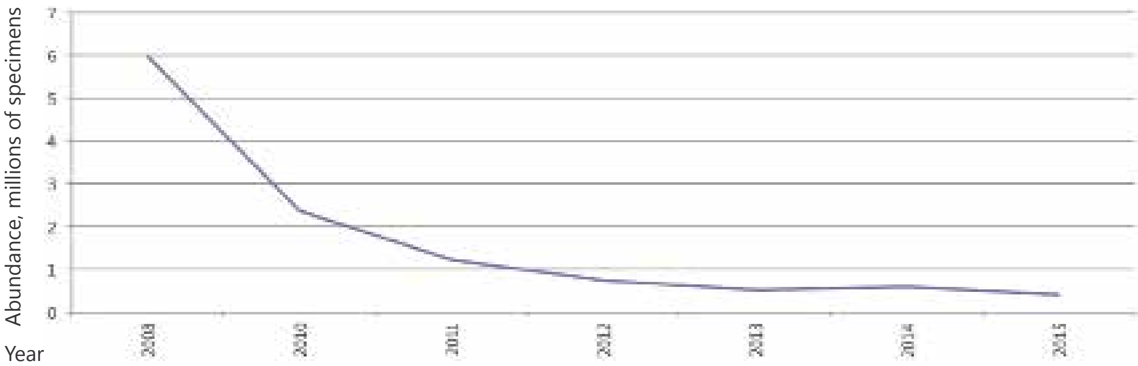


Figure 10.3.4 Changes in Russian sturgeon abundance in the North-East Caspian Sea water area

Persian sturgeon. Persian sturgeon is distributed throughout the entire Caspian Sea, but it fattens mainly in the South and North Caspian Sea. A smaller number enters the Volga and Ural Rivers for wintering and spawning. The Persian sturgeon breeding takes place in the Ural River in the same areas and in the same periods as the Russian sturgeon. Its wintering grounds are located in deep holes of the upper section of the spawning zone and it spawns in the first half of May, when the water temperature is 9–12˚C. Sexual maturity is reached at the age of 7–8 years for males and, a bit later, at 9–10 years of age for females. The gender ratio is usually close to 1:1 [Fish of Kazakhstan 1986].

The Persian sturgeon has an uneven distribution across the Caspian Sea. Persian sturgeon catches are episodic and irregular by nature. It is found rarely in North Caspian Sea breeding areas.

The size and weight composition of the Persian sturgeon population in the North-Caspian Sea water area is presented in Figures 10.3.5–10.3.6.

Figures 10.3.5 and 10.3.6 indicate that there is no regularity in the Persian sturgeon changes of its linear and weight variables. Probably it is explained by non-availability of sufficient data to make any conclusions regarding dynamics in linear and weight variables. This is not surprising because the North-East Caspian Sea water area is a periphery in their habitat. Thus, given the specifics of the spatial distribution of the Persian sturgeon in the Caspian Sea and dynamics of its abundance in the North-East Caspian Sea water area (Figure 10.3.7) it would be wrong to perform any assessment of its population structure, based only on the available data.

Stellate sturgeon. The natural habitat of the

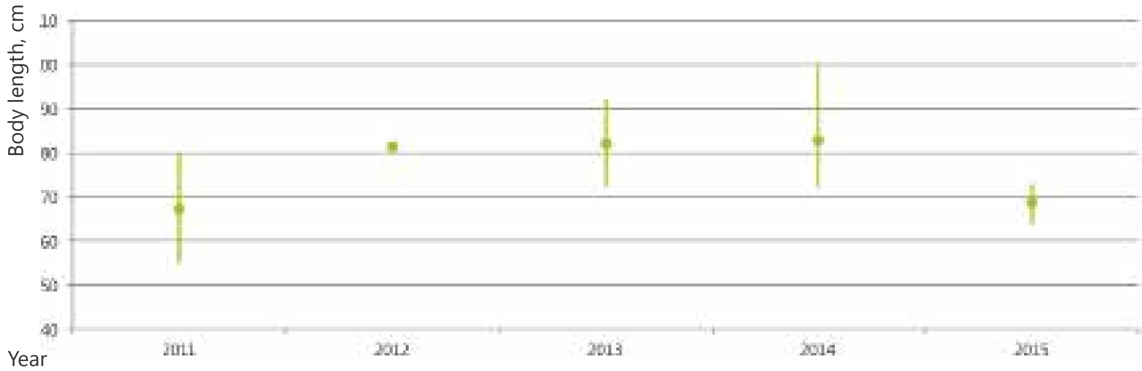


Figure 10.3.5 Size composition of the Persian sturgeon in the North-East Caspian Sea water area

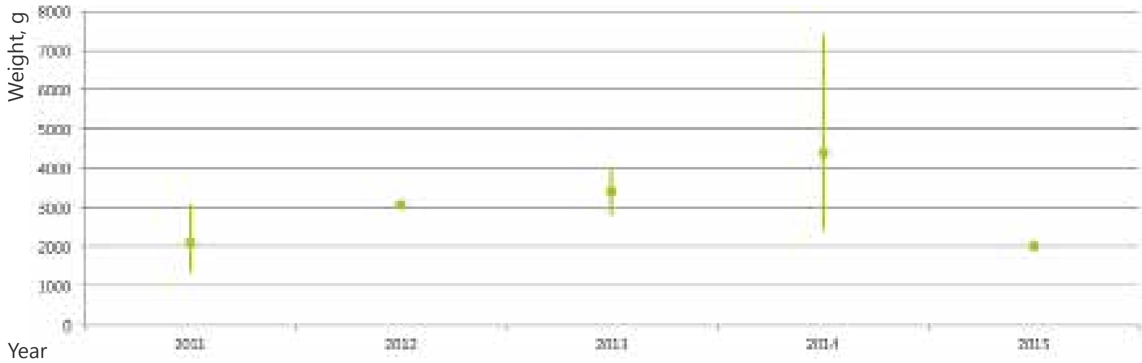


Figure 10.3.6 Weight composition of the Persian sturgeon in the North-East Caspian Sea water area

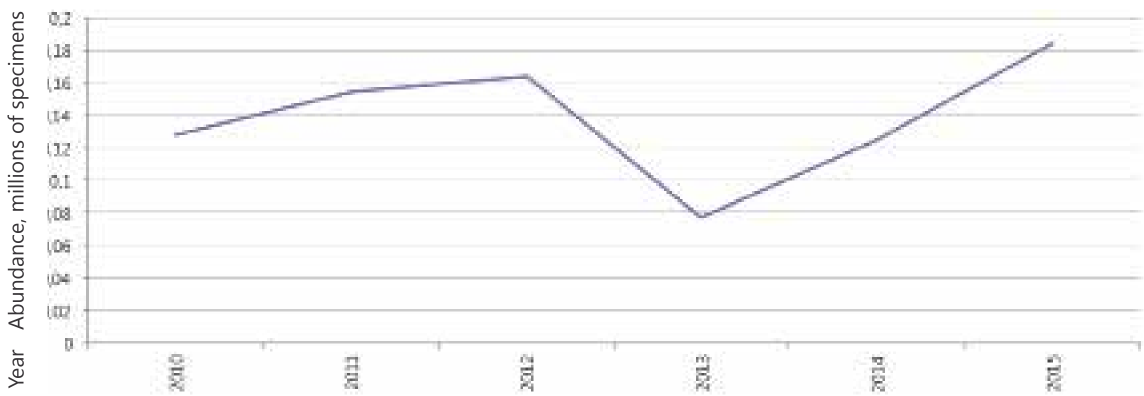


Figure 10.3.7 Changes in Persian sturgeon abundance in the North-East Caspian Sea water area

Stellate sturgeon includes the basins of the Black, Azov and Caspian Seas. The Ural River is the habitat for three forms – hiemal, early vernal and late vernal. The proportions of the various forms in the spawning population is not even, with the hiemal and late vernal forms accounting for at least 10-15%. It differs from other Caspian sturgeon by its quick maturity, its relatively short inter-spawning intervals, the absence of non-migratory forms and its unique body form. The Stellate sturgeon is a migratory fish, spending the majority of its life cycle in the sea where it fattens [Fish of Kazakhstan, 1986, Kazancheyev 1981].

The Stellate sturgeon spawns in Kazakhstan in the Zhaiyk River. Apart from the difference in the periods of its entry to the river and its wintering grounds, the various forms of Stellate sturgeon differ in spawning time and temperatures. Thus, the hiemal Stellate sturgeon spawns when water temperature reaches 13–17˚C, at the distance of 650–950 km from the sea, during 10–15 days. The early vernal form spawns when water reaches the temperature of 15–25˚C, 15–25 days after the vernal form, while the late vernal form spawns when water temperature reaches 20–26˚C at the distance of 650 km from the sea [Fish of Kazakhstan, 1986].

Stellate sturgeon becomes sexually mature at the age of 4–6 years for males and 7–8 years for females. However, end masse, sexual maturity arrives later. As such, the majority of males reach sexual maturity at 7–9 years of age, and females at 11–13. Breeding Stellate sturgeon miss spawning, with young males spawning every 2–3 years, and females once every 3–5 years. Adult male and female spawn every 4 years [Fish of Kazakhstan, 1986].

The size and weight composition of the Stellate sturgeon population in the North-East Caspian Sea water area are presented in Figures 10.3.8–10.3.9.

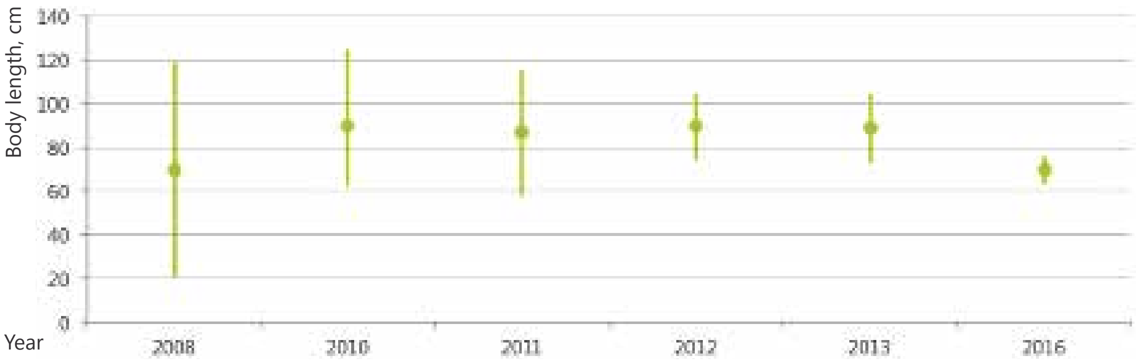


Figure 10.3.8 Size composition of Stellate sturgeon in the North-East Caspian Sea water area

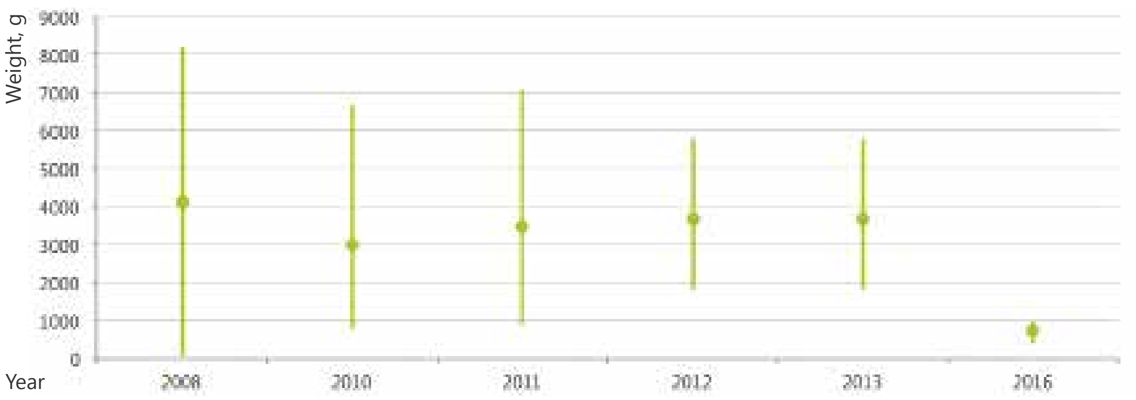


Figure 10.3.9 Weight composition of Stellate sturgeon in the North-East Caspian Sea water area

Figures 10.3.8 and 10.3.9 show a narrowing range in the values of body length and weight in catches of Stellate sturgeon. Similar to the Russian sturgeon, the reduction in maximum linear and weight variables is determined by increase in the morbidity rate and reflects a reduction in size and weight ranges, while the increase in the lesser size and weight variables of specimens in 2010–2013 means lack of replenishment during the period under review. This assumption is confirmed by dynamics in the age structure of the Stellate sturgeon population as presented in Figure 10.3.10.

Figure 10.3.10 indicates that the period 2008–2012 saw an increase in maximum ages in the population, with no young fish recorded in catches. The nature of the increase in the maximum age in catches is not related to the growth in population abundance, but it is rather a consequence of catches of residual species of 1998 large population. This is confirmed by a significant drop in maximum observed ages after 2012 and the absence of Stellate sturgeon in control trawl surveys in 2014–2016.

It is evident that Stellate sturgeon abundance in the North-East Caspian Sea water area in the period under review keeps decreasing steadily. In 2015, Stellate sturgeon abundance in the water area amounted to 117,000 specimens.

The decrease in maximum Stellate sturgeon linear and weight parameters and changes in age structure and abundance in the North-East Caspian Sea water area confirms ongoing degradation of species populations.

Thus, according to fishery surveys, sturgeon catches were reduced in the North-East Caspian Sea from 2008 to 2015. The catches of beluga and Persian sturgeon were sporadic and did not allow accurate assessment of the changes in linear and weight variables due to the lack of representative samples.

The results of analysis of changes in linear and weight variables, age and abundance indicate deterioration in the condition of the populations of Russian sturgeon and Stellate sturgeon in the North-East Caspian Sea water area.

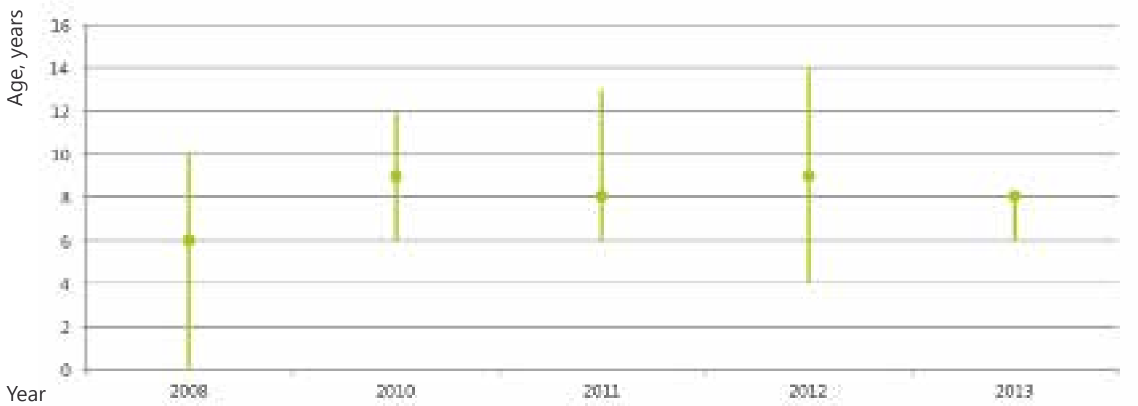


Figure 10.3.10 Change in the age structure of the Stellate sturgeon population in the North-East Caspian Sea water area

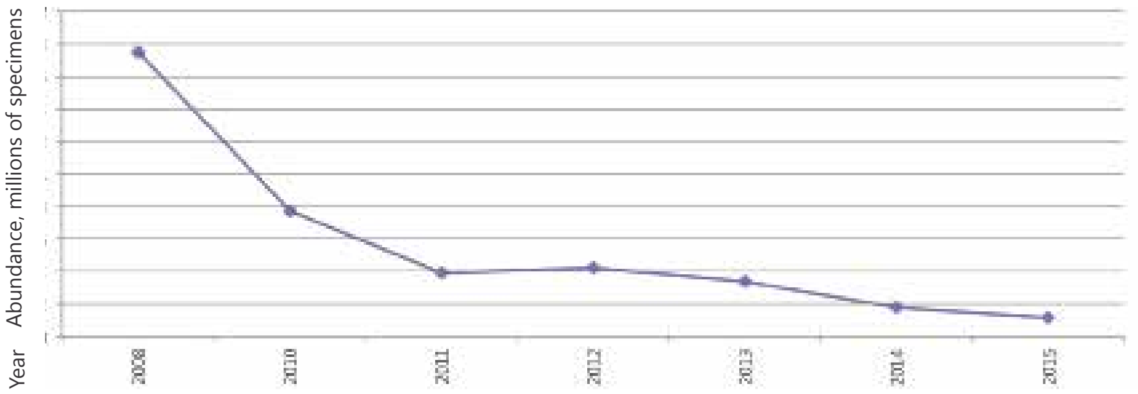


Figure 10.3.11 Changes in Stellate sturgeon abundance in the North-Caspian Sea water area

Conclusions

In total, 70 species and subspecies of fish were identified during ichthyofauna monitoring in NCOC N.V. Contract Areas and the water basin of Kazakhstan Sector of the Caspian Sea in 2006–2016 period.

The similarity quotient for the species composition of nekton and benthopelagic communities (the equivalent of the Jaccard index) is 46% [Rozenberg, 2012]. This means that approximately half of the 70 species and subspecies are found in both fish communities.

The nekton community of fish in 2006–2016 consisted of 44 species and subspecies from 9 orders and 10 families. The majority of fish species belonged to the carp family (14 species), the goby family (10 species), the herring family (7 species) and the sturgeon family (5 species). The average annual fish abundance in fixed net catches fluctuated from 476 specimens/effort to 1,013 specimens/effort. The catch biomass for the same period changed from 54 kg/effort to 171 kg/effort.

The species composition of the benthopelagic community of fish in bottom beam-trawl monitoring catches in the North Caspian Sea water area in 2006–2016 amounted to 53 species and subspecies from 7 orders and 9 families. The majority of fish species belonged to the goby family (29 species), the carp family (11 species) and herring family (5 species). The number of species from other families did not exceed 2. The average annual abundance of fish in catches varied from 373 specimens/ha to 1,566 specimens/ha. The catch biomass for the same period fluctuated between 3.2 kg/ha and 8.2 kg/ha.

Roach was found in the nekton community at least at 92% – 100% of the monitoring stations. Bream frequency was high in the range of 70%–92%. Frequency of occurrence was constantly high at 44%–75% for all 10 years for the saposchnikowii and Agrakhan shad. As a consequence of the drop in the sea level and increased salinity in the North-East Caspian Sea in the last 5–6 years, catfish and pike had completely disappeared from net catches, while predators such as zander and asp had significantly reduced their habitat.

Deep-sea fish, such as sprats, roach, bream and sand smelt had an even distribution in the water area in the benthopelagic community. Moreover, sand smelt had gradually taken over new territories. Several goby species from the big head goby order were only observed in the first five years, and then practically disappeared from the studied water area. The longtail dwarf goby, goad goby and Knipowitschia iljini had significantly reduced their habitat by 2010 and were rarely observed. Even the predominant monkey goby was observed less frequently.

A simple and reliable way of indicating species richness is to trace the quantity of fish species at one monitoring station in a specific water area. This variable for benthopelagic community and nekton community had been gradually decreasing since the beginning of monitoring till 2013. The reduction in species composition in the surveyed water area can be an indicator of impact of a number of unfavorable factors on the North Caspian Sea ichthyofauna, which requires a careful study.

According to "significance" parameter, 10 species of fish forming the community core had been identified in net catches in the nekton community in 2006–2016. They included Stellate sturgeon and Russian sturgeon, three species of shad – North-Caspian, saposchnikowii and Agrakhan shad, roach, asp, bream, common carp and zander.

The abundance of the largest two fish species of the sturgeon family — the Stellate sturgeon and Russian sturgeon, reached its predicted minimum in 2014 and 2015. Analysis of changes in the abundance of sturgeon in Kashagan East and Kalamkas water areas showed a similar reduction in sturgeon abundance at both locations, which are 120 km away from each other. Over the 11-year period, a similar reduction in the size ranges was noted for the Russian sturgeon both for large and small specimens. This can confirm an increased elimination of sturgeon breeders, for example, as a result of poaching, which, in its turn, leads to deterioration in reproduction and reduced population replenishment with young fish.

Thus, the operations at the fields are not a determining contributor in the catastrophic reduction in valuable sturgeon abundance.

The main reasons for the unfavorable impact on the populations of these ancient ichthyofauna representatives existed much earlier than the start of offshore development in Kazakhstan Sector of the Caspian Sea. Such reasons are well known. They include river regulation, water environment pollution, overfishing, poaching and others. Thus, the current situation requires immediate environment protection actions or even legal intervention.

The change in roach abundance is most stable at Kashagan water area. The fluctuations in species abundance over the years had not been significant and remained within the range of 300–500 specimens/effort. Changes in roach abundance in the area of the Oil field pipeline route are less stable and can fluctuate significantly in different years. At Kalamkas field, roach abundance is lower than at other locations and tends to further decrease possibly due to changes in sea water salinity.

The benthopelagic community core includes 8 species of fish: 4 deep-sea species — Black Sea-Caspian sprat, roach, bream and sand smelt, and 4 bottom dwellers — monkey goby, goad goby, bighead goby and longtail dwarf goby.

Changes in Black Sea-Caspian sprat abundance over the years at all monitoring sites are irregular and not dependent on any specific water area. Sand smelt abundance in all years was at its highest at Kashagan East and Kalamkas and has shown growth trends at all locations. Bream abundance is distributed according to salinity levels. Lower bream abundance in all years was observed at Kalamkas field, with the highest abundance observed at Kashagan. The highest bream abundance was typical for the coastal section of the Oil field pipeline. Changes in roach abundance over the years at Kashagan and Kalamkas are almost similar, despite 120 km distance between them. As no major operations were performed in Kalamkas area, it means that the long-term development in Kashagan East water body has no effect on the roach or on changes in its abundance.

The periods of monkey goby abundance increase can be related to the changes in turbidity and the granulometric composition of soil as a result of construction activities at Kashagan East and in the area of the Oil field pipeline. In terms of biology and biotope, the closest to the monkey goby is the longtail dwarf goby, which also prefers the Oil field pipeline water area. In other water areas, its abundance is lower. Goad goby and bighead goby, on the contrary, prefer biotopes with deep, clean and salty water. The highest abundance of these species was observed in Kalamkas water area. The goad goby is practically missing in the area along the Oil field pipeline route. This distribution of preferences for environmental niches and habitats within the goby family can be an evolutionary adaptation to species competition and a more efficient development of territories.

It is necessary to comply strictly with RoK and environmental legislation in order to minimize environmental negative consequences caused by operations in the North Caspian Sea water area.

Measures for conservation and rehabilitation of biological diversity

A systematic environmental approach shall form the methodological basis for conservation of biodiversity. Such approach would allow assessing the biodiversity of live organisms at various hierarchical levels, such as integral space-time and the functional structure of the biosphere. Conservation of species is not possible if conditions for their habitat and functional links between various components of the biota and abiotic environment are not provided.

For the purpose of biodiversity conservation in the water basin and coastal area in Kazakhstan Sector of the Caspian Sea, the package of existing and partially implemented plans shall be supplemented with the following:

- Develop a Unified National Program to monitor wildlife in the framework of State Environmental Monitoring on a regular basis, using a unified methodology and a stations grid
- Identify a coordinating body to compile and analyze the data provided by various organizations and departments, including the outcomes of operations of oil companies

- Perform inventory of all biological resources in Kazakhstan Sector of the water basin and Caspian Sea coast; establish a common database of biodiversity for Kazakhstan Sector of the Caspian Sea available for various users; organize the assessment and study of the impact of the Caspian Sea pollution on its biodiversity
- Replenish reducing fish reserves in the Ural-Caspian basin, organize the commercial reproduction of basic commercial species; and organize the artificial reproduction of endangered species (Caspian salmon, sheefish and others)
- Develop a system of measures to ensure compliance with the ban for sturgeon sea fishing
- Assess the efficiency of artificial reproduction of sturgeon; assess potential consequences for the sturgeon Geno fond and increase of the proportion of breeders from artificial reproduction
- Increase the efficiency of dredging in the delta sections of the Zhaiyk and Kigach Rivers
- Perform an inventory of water intakes on the Zhaiyk and Kigach Rivers; assess the efficiency of fish protection devices installed at such water intake points
- Enhance the efficiency of incentive mechanisms for conservation of flora and fauna bio resources in the Caspian Sea
- Improve the system for protection of valuable objects, rare and endemic species
- Promote environmental awareness and involve the public in discussions of the Caspian Sea issues and conservation of its biodiversity; arrange academic and scientific publications regarding the Caspian Sea issues and its biodiversity.

To address the current situation, comprehensive reforms are needed (in legislation, the structure of environment protection activities and others), that would create conditions ensuring efficiency of increased costs in conservation of biodiversity.

11. CASPIAN SEALS

The Caspian seal (*Pusa (Phoca) caspica*) is the only representative of aquatic mammals in the Caspian Sea. The stability of its population and abundance can serve as an indicator of the well-being of the ecosystem. The reasons of decrease in the Caspian seal population are a matter of cocern for scientists, environmentalists, governmental bodies and the global community for many years.

The Caspian seal belongs to the pagophile group of seals. Its pupping, pups' feeding, breeding and moulting occur on the ice in the North Caspian Sea (January–March). In order to complete moulting in case of early ice melting in spring and for autumn rookeries before the ice is formed, seals use islands, stone outcrops, sand banks and gently sloping coastal areas that are not overgrown with reeds and other high plants. However, the Caspian seal makes use of the water environment for the majority of the annual cycle. Every year, the majority of the population (up to 90%) perform a spring trophic migration (April — May) to the Middle and Southern Caspian Sea for fattening (June — September) and return in autumn (October — November) to the North Caspian Sea for breeding on ice [Badamshin, 1966]. One of the reasons why seals migrate from the shallow northern section of the Caspian Sea to the south in spring is a high water temperature in summer which the Caspian seal tries to avoid.

The Caspian seal is a predator and a representative of the high trophic band. During the ice-free period (open water period) it has no enemies. In winter, during the pupping season, which takes place in water area ice, the new-born pups become an easy target for eagles and wolves.

Over many centuries, the Caspian Sea has been one of the most productive regions, with seals successfully inhabiting it, maintaining their abundance, even though it was subject to intensive hunting by the people who lived on the northern coast of the Caspian Sea.

During the previous century, Caspian seal stock was determined with use of indirect methods based on changes in annual hunting levels, the size of pupping grounds on the ice, hunting of pups on breeding grounds and others. [Dorofeyev and Freiman, 1928; Roganov, 1932; Badamshin, I960, 1966, 1969; Chapskii, 1963 et al]. These assessment methods provided only estimated details of Caspian seal population and its abundance.

A review of references shows that in the XIX century and at the beginning of the XX century, the total stock of the Caspian seal exceeded 1 million, which allowed its hunting in the period 1824–1915 at the level of 150–225 thousand specimens per year [Arsenyev et al, 1973; Geptner et al, 1976]. According to Badamshin and Chapskii, the total abundance of the Caspian seal was considered to be approximately 750,000 in the 1950s, and about 470,000-600,000 in the middle of the 1960s [Badamshin, 1960, 1966; Chapskii, 1963]. According to scientists from the Institute of Biology, the University of Leeds, [S.Goodman, L.Dmitriyeva and S.Wilson, 2014 et al] the most realistic assessment of Caspian seal abundance was made at the beginning of 1966 (470,000-520,000), when it was assumed that almost 88,500 puppies had been killed), the calculations of the total stock abundance were based on discretionary percentages of immature juvenile and reproductive adult specimens summed up for both genders [Badamshin, 1969].

The first aerial survey of breeding females on breeding grounds (ice) was conducted in 1973, and it allowed to determine more accurately the total breeding stock abundance of 90,000 species, and the total livestock population of 450,000 specimens [Krylov, 1976]. In subsequent years, mainly visual aerial surveys were performed.

The intensive hunting of Caspian seals, which continued till the end 1960s, and deterioration of environmental conditions in the Caspian Sea (Volga River inflow) control resulted in significant decrease in Caspian seals abundance. The measures to regulate hunting taken in 1970 allowed somehow to stabilis its population which stayed at the same level till the 1980s [Krylov, 1990].

According to Russian authors, the population of the Caspian seal is currently in depression, which is evident from reduction of reproductive abilities of the livestock by 60-63% [Khuraskin and Zakharova, 2000, 2001]. Reports on seal surveys performed by NCOC N.V. in 2005-2012 indicated that the reduction in reproductive capacity of livestock was in the range of 50% — 70%. [CISS 2005-2012].

Some experts believe that the main reason of decrease in abundance and reproductive capacity of the Caspian seal livestock was a significant chemical pollution of the Caspian Sea with industrial and agricultural wastes, and subsequently, high levels of organochlorines and heavy metals in seal organs and tissue [Krylov et al, 1986; Krylov, 1990; Khuraskin, 2002]. Spring 2000 (April-June) saw a mass death of over 30,000 seals of different ages. Scientists believe that the death was caused by chronic toxicosis leading to weakening of their immune system and the spread of parasitic and infectious diseases, such as haemorrhagic septicaemia and salmonella combined with canine distemper [Miyazaki et al., 2002].

The results of surveys performed by various authors were mainly similar and confirmed a trend in decrease of the Caspian seal abundance in the period from the end of the XX century till the beginning of the XXI century, however, its reasons, despite many hypotheses, were unclear.

Currently with intensive hydrocarbon exploration and production in the North Caspian Sea, annual aerial surveys of the Caspian seal abundance and field surveys were organised to understand impact of sea vessels on seals population. Such surveys indicated that while the Caspian seal population was 1 million species at the beginning of the XX century, it was only 100,000 species at the beginning of the XXI century. One of the reasons for reduction in seals abundance can be the seals' consumption of fish that have organic chloride compounds in their systems (organochloride — OCs). This causes weakening of the seals' immune system and their vulnerability to diseases [Goodman et al, 2014].

Based on joint surveys (2005-2007) performed by scientists from the St. Petersburg State University, the British University of Leeds and the International Union for Conservation of Nature, in 2008, the Caspian seal was classified as "being under threat of extinction" and entered into the Red Book.

NCOC N.V. HAS ALWAYS RECOGNISED A NEED IN SURVEYOF SEALS' MIGRATION, USE OF HABITATS, AND THEIR RESPONSE TO MOVEMENT OF ICEBREAKERS, BECAUSE UNDERSTANDING OF THESE ASPECTS OF THE SEALS' LIFE-SUSTAINING ACTIVITIES MAKES IT POSSIBLE TO MINIMIZE THE POTENTIAL NEGATIVE IMPACT OF COMPANY'S OPERATIONS ON SEALS POPULATION.

Therefore, seal surveys were organised with use of aircraft, icebreakers, vessels and remote sensors.

Caspian seal survey in winter 11.1

This section summarizes the results of aerial surveys and field on-board surveys to monitor impact of icebreakers on the Caspian seal population during 2005-2016 sponsored by NCOC N.B. [CISS, 2005-2012, International survey ..., AGIP KCO/NCOC, 2009-2012; Monitoring the impact ..., NCOC N.V., 2014-2016].

The aim of such surveys was to identify the abundance of Caspian seals and develop recommendations and measures to reduce the impact of icebreakers on their population during pupping and pups' feeding periods.

Survey methods

Aerial surveys. The counting of Caspian seals was planned in the way allowing to surveyobjectively the entire ice cover: from its edges in the south, and then further to the north, east and west till the locations where the water depth under the ice is sufficient enough to form habitats for seals. Surveys in the Baltic Sea indicated that the most efficient counting is achieved when the percentage of the area under surveyis 8-15% of the entire ice cover. Thus, the counting is not fully dependent on the density of seal groups distribution or assumptions regarding their distribution.

L-410 fixed wing was used for aerial surveys in 2005-2012, whereas it was a rotary wing AW139 in 2014-2016 (Figure 11.1.1). Surveys were usually conducted in the later part of February. During the survey period, surveyors used a recording band methodology that was originally developed for counting Baltic ringed seals and then adapted to the Caspian conditions [Härkönen and Heide-Jörgensen, 1990; Härkönen and Lunneryd, 1992]. It was assumed that by the end of February, all pups had been born already [Krylov, 1990]. The flights were made at the speed 150-250 km/h at the height 90-100 m. The stable height was maintained with the help of a radar altimeter. The width of the recording band was 800 m in total, with 400 m on each side of the airplane or helicopter.

In order to count Caspian seal abundance in 2005-2012, the recording bands were planned longitudinally every six minutes. The airplane flew along the recording bands, from the north to the south and then from the south to the north, thus, covering the whole range of potential seal habitats on the ice in Kazakhstan Sector of the Caspian Sea.

The objectives of the helicopter surveys (2014-2016) were to identify seal rookeries, record their locations, identify the density of animals and plot them on a map in accordance with the nature of their distribution across the ice. Such approach allows correct planning of icebreaker routes and reducing any man-caused impact on the seals during the breeding cycle.

Each aerial survey was preceded by review of ice maps from NASA site (Lance-Modis). This was necessary for surveyof certain ice cover areas bordering with the open waters, where the seals concentrated during a breeding season.

Two observers were present on airplane (or helicopter) during each flight to count seals and eagles along the 400 m recording band. At the same time, two specialists took video and photos. Comments on the visual observations were recorded with Dictaphones synchronised with GPS-navigators, in addition to the photo recordings [NCPOC Instruction on Aero visual Survey, 2012].

During a careful review of photos, "mother/pup" pairs, single pups, single adult seals (without pups) and white-tailed eagles were counted. Special attention was given to the cases when photographs overlapped to ensure than each animal on the photograph was counted only once. Visual observations were decoded and linked to geographical coordinates by synchronising them with GPS-navigators and cameras. Observations of each observer and coordinates were then included into a table for spatial analysis.

The data of photos taken during a duplicated photo survey (a photo survey conducted by two observers on each airplane), where individual animals could be seen, was also linked to coordinates. This allowed to assess of any potential systematic errors in identification of animals using analysis by tagging, releasing and recatching method (TRRC). The analysis was based on sample collection and duplicated sample

Fixed wing L-410
Counting of seal abundance in the North-East Caspian Sea on the surface of the ice cover

Rotary wing AW139
Recording of seal abundance along icebreaker routes, ensuring adjustment of icebreaker routes to bypass seals grounds

Figure 11.1.1 Aircrafts used for aerial surveys of the Caspian seal collection of specific animals from photographs according to their location at a specific moment of time.

Careful review of photographs allowed to identify adult seals, pups and white-tailed eagles noted by both observers during every flight. The probability of discovering adult seals, pups and eagles was calculated for each observer on the basis of a ratio of seals noted by this observer and seals noted by the second observer.

Measurement accuracy was determined by calculating coefficients of variation (CV) for each category of animal. This employed a three-dimensional repeated selection method described by Harkonen and others. [Harkonen et al., 2008], and the TISS computer programme developed by the Swedish Museum of Natural History.

The density of seals in areas not covered by the survey (i.e. in the areas between the survey bands) was determined on the basis of inverse distance-weighted interpolation from the surveyed points along the transects. After the interpolation, sporadic exponentially distributive hindrances were added in order to restore the initial spread and dispersion in the groups. Density was expressed as the average number of animals per km^2. Density maps were developed based on survey data generated by the kernel interpolation method using the ArcGIS 10.0 programme.

The final assessment of seal abundance was made based on comparison of data acquired by each specialist. In future, this information was used to assess the nature of the Caspian seals distribution on ice and plot it on the maps using indexed coloured zones.

Icebreaker surveys. Kashagan field operations are supported with icebreakers used to pilot vessels. The icebreaker surveys are aimed at studying seal behaviour when they stay in proximity to vessels and develop recommendations to mitigate their impact.

Observers staying on icebreaker bridges shall record the reaction of seals, especially mothers and their pups, to approaching icebreakers. The level of successful route planning was assessed by registering all pups within a 150 m range from each icebreaker along the routes between Bautino and Kashagan during the winter navigation period. The distance of pups from icebreakers recorded by observers was then compared with the general distribution of pups identified during special aerial surveys conducted to determine the most efficient and environmentally friendly routes.

The team of seal observers carried out continuous observations from the bridge during icebreakers movement through the ice to Kashagan field and back. [NCPOC B.V. Guidelines for Icebreaker Observers, 2012]. When an icebreaker entered the areas where presence of seals was expected, two people kept watching on each side of the bridge. In all other cases, two observers (one on each side) or one observer in the centre of the bridge kept watching. When moving through the areas with supposed concentrations of seals during the night time, the entire team of observers was mobilised on the bridge (two observers on each side). Tracks (path with coordinates) were recorded with the help of GPS-navigators on each side of the bridge from the beginning to the end of the route.

Seal observers on each side of the bridge used binoculars to check the ice cover in front of them and on each side of the icebreaker. All seals and their numbers (single adults — SA, pair "mother-pup" — MP, single pup — SP) were registered. Distances from the icebreaker were measured using a laser distance gauge. Seals encountered on the route were photographed from each side of the bridge, whenever possible, using a digital camera with an adjustable lens. The locations of all seals and their groups were noted within 150 m range from the icebreaker.

A checklist divided into blocks of 4 hours, for each observer's shift was used to register information on all seals encountered. The following data was entered in the checklist:

- Report number (i.e. the number of the four-hour report)
- Name of the seal observer
- Registration time of encounters
- Number of the route GPS point
- Seals (pair "mother-pup", single pup — SP, single adult — SA) and their number
- Distance from the icebreaker to the seals
- Number and availability (yes/no) of photographs

- Notes, incidents registration (including "major", "medium" and "minor" events), the location of the seals (ahead of the icebreaker, in the water, on the ice, etc.)

Each time when travelling by an icebreaker, the observers on board completed checklists on each side of the bridge, taking notes of all encounters with seals at the distance of up to 150 m from the vessel. When discovering seals on the icebreaker route in the 150 m zone, the observer, performed the folloving duties:

- Warned the captain or shift assistant about the animals and recommended a possible manoeuvre;
- Noted the coordinates of the encounter with the seal in a GPS-navigator;
- Recorded the encounter with a camera;
- Made entries in a survey log sheet recording the time, the distance from the vessel to the seal and the development stage of the puppy; categorised each event according to its danger (pursuant to the Guidelines for Seal Observers), provided a brief description of the animals' reaction to the danger and any actions and manoeuvres taken by the vessel team.

Encounters with seals were recorded and classified as "major", "medium" and "minor". Major events or incidents involved fatal consequences/ collisions with the icebreaker, the complete separation of a new born pup with its mother and the separation of a mother from its pup at the distance ≥20 m, pup soaking and destruction of a pupping and pup feeding grounds. Medium importance events included a vessel moving at 50 m distance from a pup, relocation of a pup >20 m and a mother's separation from its pup at 20 m distance. Minor events were registered when vessels were travelling within 50-150 m range from pups. Examples of various impacts on seals during the icebreaking period are given in Figure 11.1.2.

Using this data, a four-hour summary checklist was completed to indicate the number of adult seals, including single adults, "mother-pup" pairs and single pups, at the distance of up to 150 m from the icebreaker. After a four-hour shift, report findings were processed by observers with the help of the Seal Observation SW programme. As soon as the data was processed the findings of encounters with seals and their locations indicated in a PDF and XML sheet were sent by email from the vessel to the NCOC N.V. ice department and logistics department.

After each recording, the material was analysed and indexed according to a colour scheme on the basis of the number of specimens encountered at each point in order visualise their density (Table 11.1.1). This method was developed by experts of CISS international group (*Caspian International Seal Survey*) together with NCOC N.V. In the tables, green colour means that single seal specimens were encountered, for example, a "mother-pup" pair. Yellow colour means small groups of seals made up of 4-5 specimens with non-dense distribution. Orange means groups of breeding seals and pups. The "Importance Index for Seals" (from 1 to 12 and above) was developed for quick notification about seal density and it is presented in Table 11.1.1.

Use of contemporary methods and their enhancement for application in the Caspian Sea improves the quality of water area records of animal abundance and development of safe icebreaker routes, thus ensuring minimum

Major Medium Minor

Figure 11.1.2 Typical impact of icebreaker on seals

Table 11.1-1 Indices to identify the density of seal concentrations

Colour on annual density maps for the distribution of pups per km²	Importance index for seals, with a colour scale for navigation recommendations	Information of recorded pups	Speed recommendations
0,1-1	Take into consideration — exercise caution	If pups are not densely distributed or in large groups they are difficult to spot	When seals are seen, be prepared to reduce speed to 4 knots and change route
1-5	Take into consideration — exercise extreme caution	Be ready for the sudden appearance of seals on the route taken	Continue to travel at 4 knots, reduce speed to 3 knots if seals are close by
5-12	Avoid	Groups of breeding seals may be several km away and avoiding them without causing serious concern may be hard	Be prepared to avoid seals or stop to let them leave
12-ден астам	Avoid	A stable dense colony; a safe movement is impossible	Reduce speed; reduce speed to 3 knots; manoeuvre and stop, giving the seals time to leave

Note: 1 knot = 1.852 kmh

disturbance to the Caspian seal population during the pupping and pup feeding periods.

11.1.1 Survey results

The Caspian seal is one of the smallest seals, with adults growing up to 125-155 cm and with a body mass of 50-60 kg. During the highest fattening period (late autumn, beginning of winter) large seals can reach 85-90 kg. Sexual dimorphism is poorly defined. Fat with skin accounts for 45-50% of the total seal's body weight. During breeding and moulting, the animals lose up to 40-45 kg. New-born pups are 65-75 cm long with the weigh 3.5-4 kg. During the lactation period, the average body mass of a puppy (stage I development) is 5 kg, while the body mass of a moulted young seal (stage IV development) is 10-12 kg.

New-born puppies have a soft green-yellow embryonic cover which turns white in 2-4 days after birth — development stage I, while pups in the moulting period refer to development stage II-III. After the first moulting (3-4 weeks after birth) pups take on a silver-grey colour on their back and a light-silver colour on their belly (stage IV development). The majority pups at development stage IV have easily visible small dark and light spots. By autumn, the colouring fades and takes a yellow or olive-brown tone.

Pupping and pups' feeding take place at the end of January or the beginning of February. Until the embryonic fur disappears the pups do not enter into the water. At the end of February, the moulted pups (development stage IV) leave their "puppy" ice and form independent and larger clusters. Once lactation is over, adult males approach the "puppy" grounds to mate, and later they are joined by juvenile animals who form together with adult males the so-called "breeding" rookeries. This is the time when seals start to moult. As soon as the ice melts and moulting period ends, the seals leave the North Caspian Sea and start a way of life in deep waters and feed intensively. Some seals do not finish moulting before the ice melts and they stay on the islands in the North Caspian Sea to complete moulting (moulting rookeries are observed more often on the Durnev, Kulaly, Morskoi, Svezhi, Podgornyi, Dolgii, Krugliy and Orlov islands, which together are known as the Seals Islands).

Breeding. Mass pupping takes place usually from 28 January till 15 February, however, it can start 5-10 days earlier or later in different years.

"PUPPY" GROUNDS ARE FORMED ON THE ICE IN THE URAL FURROW OR TO THE NORTH-WEST FROM KULALY ISLAND, AND IN COLDER YEARS, BETWEEN THE RAKUSHECHNAYA-ZHEMCHUZHNAYA BANKS, SEALS ISLANDS AND CHECHEN ISLANDS.

In previous years, fur seals (development stage I) were subject to hunting in these areas in the period 1-15 February, while pups of development stage IV were subject to hunting in the period 1-15 March. Females are grouped in rookeries including dozens, and sometimes hundreds of specimens. The rookeries are located on hummocked ice at a significant distance from each other. Rookeries are formed in 1-3 or more days. A female gives a birth to one pup. As a result of plentiful and frequent feeding, puppies reach 85 cm in size and their body mass increases to 14-18 kg by the end of lactation. Milk feeding lasts for 25-30 days and finishes at the end of February [Boltnyev, 2011]. Change of embryonic coat starts in two weeks after the birth and completes by the end of February. The breeding season for adult seals lasts from the middle of February (even before the end of lactation) and till early March. The gestation period for seals is 11 months. Sexual maturity of female seals is achieved at the age of 5-7 years and of males at the age of 6-8 years. The percentage of female infertility changes every year in the range of 33% — 61%.

The total morbidity of puppies in the first year of life is 25%, and it is 0.6-1.7% for juvenile and adult animals. The enemies of the Caspian seal are the white-tailed eagle, golden eagle and wolves, which probably do not have a tangible impact on Caspian seal population. The life expectancy of a male seal is 44-47 years and 35-50 years for females [Krylov, 1986].

Aerial surveys 2005-2012. The aim of aerial surveys is to determine Caspian seal abundance in Kazakhstan Sector of the Caspian Sea during the pupping and pups feeding periods (Figure 11.1.3).

The first aerial survey of the Caspian seal with support of the Company was conducted in 2005. Results showed that the birth rate in that year was 34,000 pups. Given the assumed level of breeding, the total population of the Caspian seal was estimated at 96,966 species [Harkonen et al., 2005; Harkonen et al., 2008]. Between 2005 and 2012, surveys were performed on an annual basis, and up to date their results indicate a fluctuating breeding trend for seals (Table 11.1.2 and Figure 11.1.4).

During the survey period, four main fluctuations in seal reproduction were identified. They are more or less similar (65-70% as compared to 2005-2006 estimation): decline in 2007-2008, increase in 2009, decline in 2010 and increase in 2011 and 2012 (Figure 11.1.4). According to the hypothesis of scientists these fluctuations can relate to short-term changes in such factors as abundant feed, formation of ice cover, local weather conditions and others.

According to survey outcome, the distribution and density of the Caspian seal change depending on the nature of ice distribution,

Figure. 11.1.3 Puppy rookeries

Table 11.1-2 Relative abundance of the Caspian seal in 2005-2012

Years	Total ice cover area, km2	Percentage of surveyed area, %	Total seals recorded	Total pups	"Mother-pup" pairs	Single pups	Single adults	White-tailed eagles
2005	30813	10,18	96 966	34 045 CV=4,15	30 981 CV=3,69	3 064 CV=15,83	28 879 CV=3,93	3 144 CV=13,6
2006	30824	10,03	67 019	26 378 CV=7,04	20 311 CV=9,78	6 067 CV=9,22	14 263 CV=8,64	2 073 CV=18,19
2007	10685	12,14	49540	9 371 CV=6.27	5 102 CV=7,87	4 269 CV=8,79	30 795 CV=5,00	680 CV=33,56
2008	29754	13,88	40 870	9 107 CV=5,14	6 932 CV=6,16	2 175 CV=12,83	22 656 CV=4,57	1 268 CV=12,93
2009	26856	10,36	89 720	27 226 CV=8.16	16 769 CV=7,37	10 457 CV=11,23	40 258 CV=4,56	1 120 CV=29,81
2010	26972	9,87	22 772	8 236 CV=6,85	4 029 CV=9,96	4 207 CV=9,19	6 300 CV=6,94	544 CV=44,73
2011	21373	12,24	83 710	31 022 CV=5,16	17 550 CV=4,96	13 472 CV=5,92	21 666 CV=3,63	1 831 CV=17,06
2012	29754	9,83	88 564	22 292 CV=6,24	15 077 CV=6,31	7215 CV=8,87	43 980 CV=4,91	2 469 CV=9,63

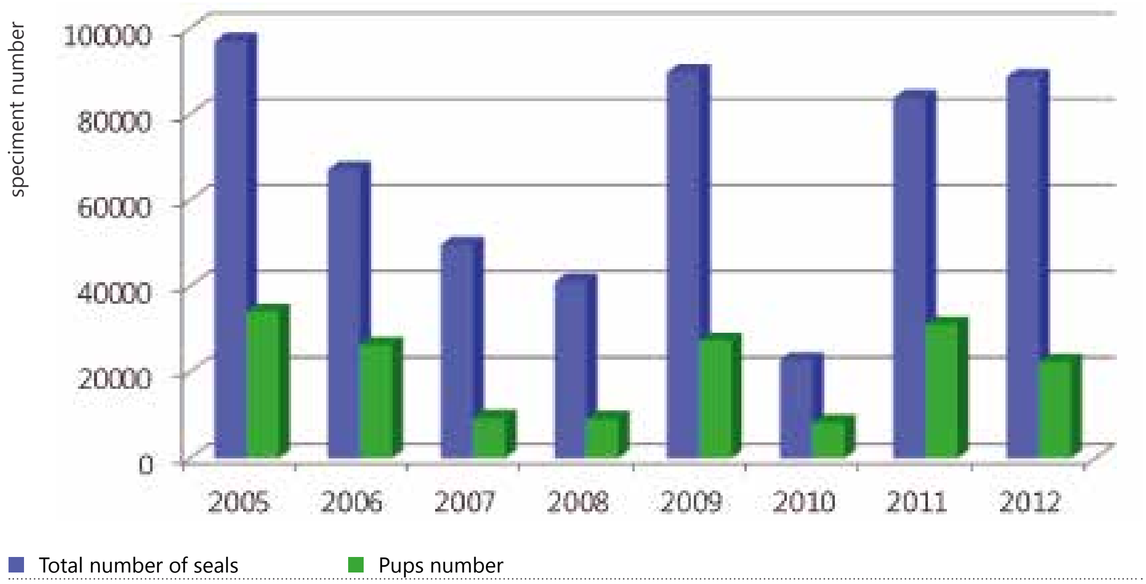


Figure 11.1.4 Relative abundance of seals and pups according to aerial surveys in the Kazakhstan Sector of the Caspian Sea

bathymetry, productivity and other factors. Figure 11.1.5 shows the winter distribution of seal pups established during aerial surveys in different years in winter period.

In 2005, 2006, 2008 and 2009, when ice cover was not well developed in February in the Caspian Sea, the densest concentrations of pups were noted in the saddle area (the seabed section to the south-west of the Ural Furrow) (Figure 11.1.5).

Due to unusually mild winter in 2007, only a strip along the north-eastern coast of the Caspian Sea was covered with ice, and as a result the distribution of breeding seals was limited to a small area in very shallow waters (1-3 m).

In 2012, when the ice cover was more extensive, pups' grounds were concentrated in the southern and western areas, which had not been the case in previous years. The densest concentrations of pups were located on floating and less floating ice fields to the west from Kulaly island, on the ice edge between the Malyi Zhemchuzhina island and Kulaly island and on the ice edge in the saddle area (Figure 11.1.5).

Such distribution of seals in 2012 was in line with locations of the Caspian seal breeding grounds in moderate cold and severe winters in the XX century [Badamshin, 1968]. Eastern and south-eastern winds at the end of January and beginning of February caused the destruction of the ice edge which was occupied by breeding seals in the eastern breeding grounds, and movement of ice with seals to the west. A similar situation was observed in winter 2010, when in the period from January to the middle of February, the main ice fields (where breeding females were possibly present) moved from the eastern sector of the North Caspian Sea to the west, and the majority of pups were found in the south-western area (Figure 11.1.5).

Modelling of the relationship between seal density and environmental factors impacting their habitat, could help to assess the impact of these factors on the distribution and abundance of the Caspian seals and predict their probable appearance in a specific region. It would help to identify important habitat characteristics to assess the environmental risks for the Caspian seal population. Furthermore, spatial modelling of selective data (modelling of surface density) could be used in future to assess population abundance by predicting seal density based on the values of specific physical and natural factors (for example, bathymetry, ice conditions, distance from the shore, proximity of industrial facilities, productivity and sea surface temperature).

Icebreaker surveys in 2006-2016

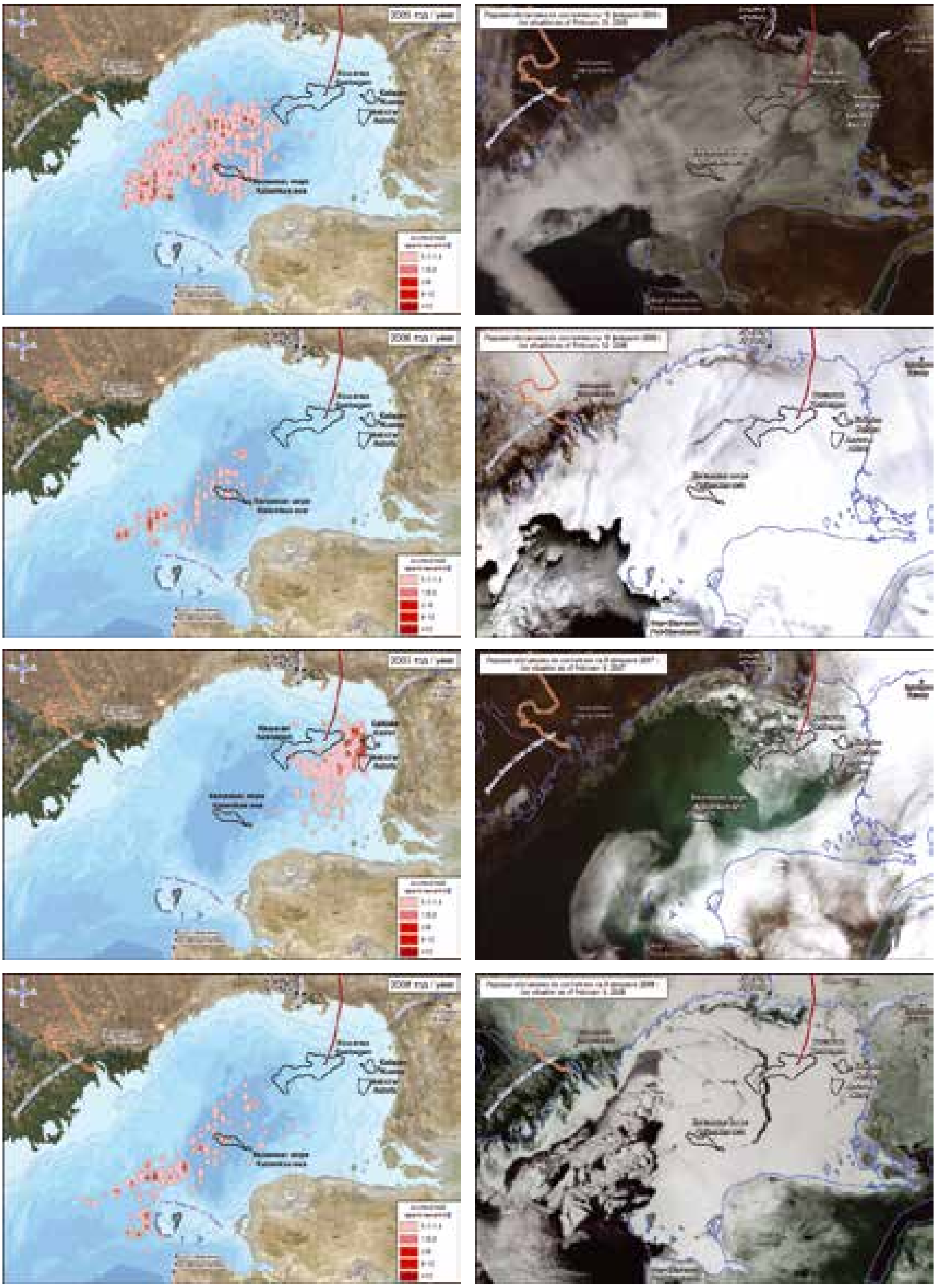
The Company organized the observation of seals from icebreakers and vessels in the period of 2006-2016 with the aim to:

- Take records of breeding seals on the ice in the North-East Caspian Sea along the icebreaker traffic corridor in order to clarify the distribution of seals during the pupping period, which coincides with the winter navigation period
- Assess the impact of icebreaker traffic on breeding animals and new born pups
- Develop recommendations and measures mitigate the impact of icebreakers on the population of the Caspian seals during the pupping and pups' feeding periods.

THE ICEBREAKER AND ON-BOARD SURVEYS PERFORMED IN 2006-2016 SHOWED THAT THE SEALS' BEHAVIOURAL REACTION TO PASSING ICEBREAKERS VARIED DEPENDING ON THE DISTANCE FROM THEM.

For example, in all survey years, females with pups closer than 100 m from an icebreaker, moved away as the icebreaker passed by, although females with pups close to ice hummocks moved away to a less extent than females with pups in even ice areas.

The majority of females accompanied their pups as they moved away so that the average distance between the mother and her pup did not exceed five adult seal body lengths. However, out of 197 "mother-pup" pairs noted at the distance of less than 30 m from the icebreaker in 2006, 43% were separated by a distance of more than 5 adult seal body lengths (on average, 8 adult seal body lengths). Distances between mother and pup exceeding the above average were noted when



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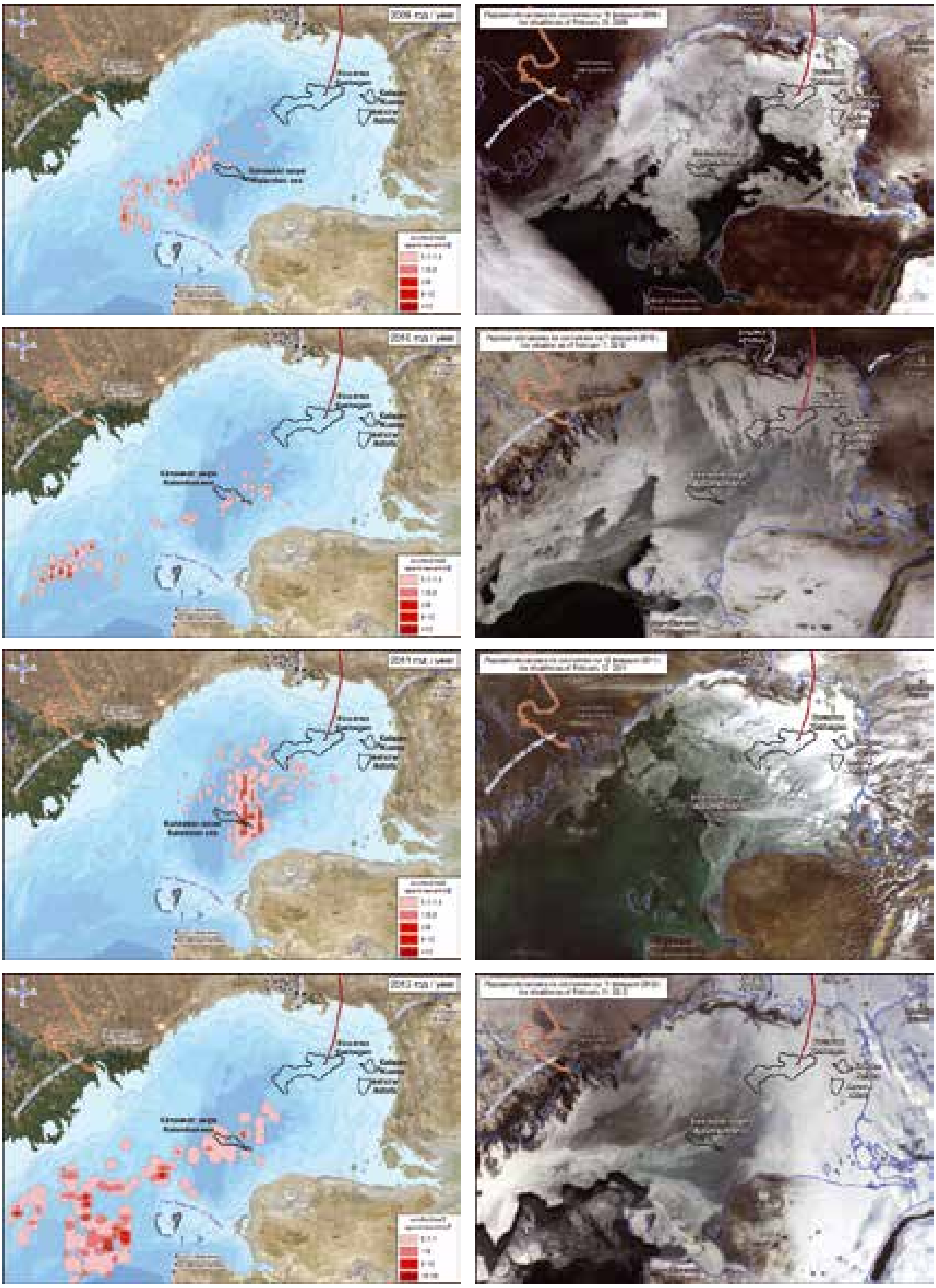


B

Figure 11.1.5 Maps of distribution of the Caspian seal pups' density in 2005–2012 (A,B) the mother "panicked" and left the area so quickly that the pup was not able to keep up.

During daylight hours, if seals stayed on drifting ice up to 50 m from vessels, practically all adults entered the water. Adult seals sometimes kept staying on ice sheets at 50-100 m distance from the vessel. If the distance to the icebreaker was over 100 m the majority of adult seals stayed on ice. White-coat pups always stayed on the floating ice. Moulted seals escaped to the water and moved to the next ice sheet if they were in the range of 50 m from the vessel.

In the day time, if adult seals stayed on fast or solid ice in front of a moving vessel, they became alert approximately at 700 m distance, and sometimes started "running". Practically all adult seals "run away" if they stayed at 500 m distance in front of a moving vessel. If the icebreaker was at 100 m and in case of open water, adult seals dived into the water. If seals stayed at 200 m distance from the side of icebreakers adults run away. White-coat pups "run away" from a vessel if they were within 75 m range, while moulted seals "run away" if they stayed at 100 m distance.

During night hours, adult seals left their ice very rarely, even when they were close to a vessel. Pups always remained on the ice. The majority of adult specimens staying on fast ice in front of a vessel at 100 m distance and sometimes at 150 m distance were able to "run away". Pups "run away" at the distance over 75 m. It can be assumed that some seals were fast asleep and did not react unless the icebreaker approached closer than 20 m. Infrared "thermal camera" and main illuminators on icebreakers were excellent means to identify seals during night hours. (Monitoring..., Agip KCO, 2008, Report on the impact of icebreakers in 2010. Agip KCO, 2011 et al).

A comparison with the results of aerial and icebreaker surveys in 2006-2012 showed that the areas with the highest distribution of pups coincided with icebreaker routes in 2006 and 2008, while in 2009 and 2010 they shifted (Figure 11.1.4). The results of aerial survey allow to conclude that the probability of pups encountering icebreakers was at its minimum in 2007 and 2009, while in all other survey years, it was higher [Report on the pilot project to reduce the impact of icebreakers on seals in 2010].

Report materials for 2005, 2006 and 2008 allow to compare the age composition of the Caspian seal identified during various types of surveys (Figure 11.1.6). The highest abundance of seals on the vessel route was noted in February 2006 (more than 12,000 seals, including approximately 5,000 puppies (white-coat pups and sivars).

According to 2008 data no concentrations of seals were observed at Kashagan. A few cases were noted at Kashagan West, no more than 5 specimens and 2-3 seals in Kashagan East area. The main seal populations were located to the south-west of Kashagan [Monitoring..., Agip KCO, 2008].

In January 2009, only 3 seal pups were encountered at 100 m distance from the vessel. This is explained by the fact that in 2009 seals accumulated to the north and west from the main icebreaker routes (Figure 11.1.5).

In 2010-2012, during assessment of icebreaker routes, encounters with seals were categorised as "major events" and "medium events." Major events included those when pups stayed directly in front or <10 m away from the icebreaker route; cases when seals died from hitting or crushing by the icebreaker; cases when white-coated pups soaked or they fell into the water; mothers and pups were separated by the distance of ≥ 100 m. "Medium events" included those when pups were at the distance of ≥ 10 m and ≤ 50 m from the icebreaker, when mother and pup were separated by the distance > 20 m and <100 m, or when mothers and/or pups were forced to move > 20 m from their original location. More than one pup or "mother-pup" pair can be involved in one event.

Reports for 2010 do not contain records on the number of seals and pups. During surveys in 2010 only "major events" were recorded with the total number 167.

The total number of "major events" observed during all six trips of the icebreaker in 2011 amounted to 52, including 28 (53%) registered by Antarktikaborg vessel moving through 70 km area of breeding grounds during eight hours in the night time. The majority of those events involved pups staying directly in front of the vessel or at <10 m distance from the icebreaker's path. The number of "medium events" in 2011 amounted to 39. Medium events occurred in area of breeding seals concentrations which was 85 km long. Those events related mainly to separation of mothers and pups by distance of > 20 m.

In 2012, in total, 23 icebreaker trips (one trip

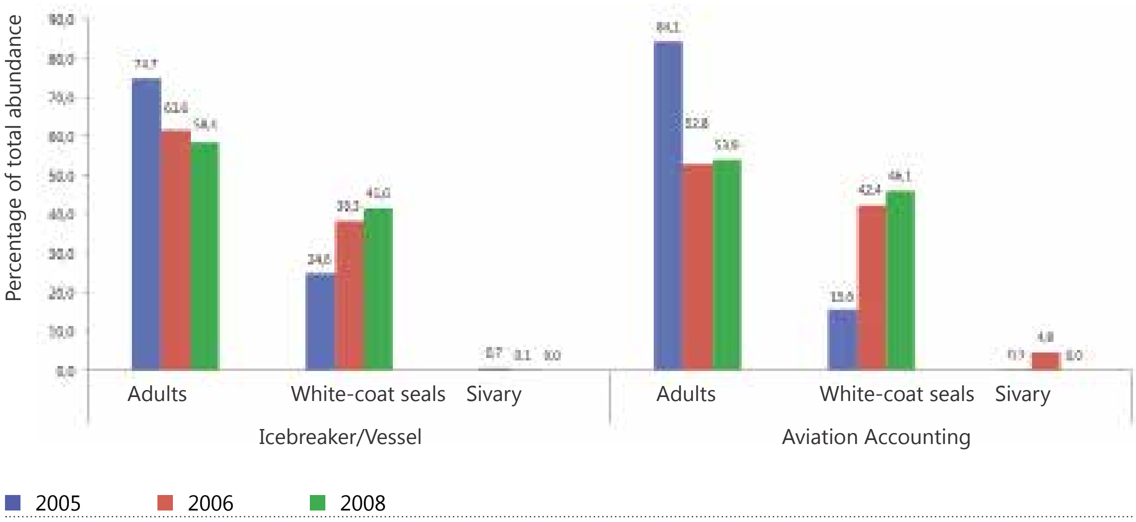


Figure 11.1.6 Age composition of the Caspian seal according to special aerial surveys and icebreaker observations

means movement of the icebreaker along the Bautino-Kashagan or Kashagan-Bautino route) were made during which seals were observed. Survey results (Table 11.1-3) allow to note that the highest number of pups observed in 2012 from the icebreakers was recorded in the second decade of December, however, they did not provide the information on the total abundance of seals encountered [Report on the pilot project to reduce the impact of icebreakers on seals in 2012]. In total, during 23 icebreaker trips made from 27 January to 6 March, 34 "major" events and 48 "medium events" were recorded.

After a break in 2013, icebreaker surveys resumed in 2014-2016, and included surveyof behaviour of females and pups along the vessel routes, assessment of icebreaker's impact on seals breeding and development of recommendations to reduce impact of icebreakers and vessels. Special attention was paid to the travelling speed of icebreakers during the winter period.

Special aerial surveys in 2014-2016 were conducted to identify Caspian seal rookeries, record their location, define their density and plot them on an index map in accordance with the nature of their distribution on ice. They were performed in order to plan environmentally friendly icebreaker routes. Aerial surveys were taken predominantly along the southern edge of the ice cover where breeding seals concentrated annually, and which was crossed by the icebreaker route with potential impact on seals populations. Such approach allows correct planning of icebreaker routes and minimizing man-caused impact on seals during the reproduction cycle (Figure 11.1.7).

Outcomes of special aerial surveys provided information of ice conditions (the concentration of ice, hummocks, snow cover, existence of cracks, ice openings, and others); the number of animals on ice (seals, white-tailed eagles and predators such as wolves and corsac); behaviour and traces of animals' vital activities.

Table 11.1-3 Number of pups located in the area up to 150 m from the icebreaker in 2012

Periods	Number of trips	Number of pups
27–31 January	1	69
1–9 February	2	55
10–19 February	3	423
20 February — 6 March	4	30
Total	**23**	**577**

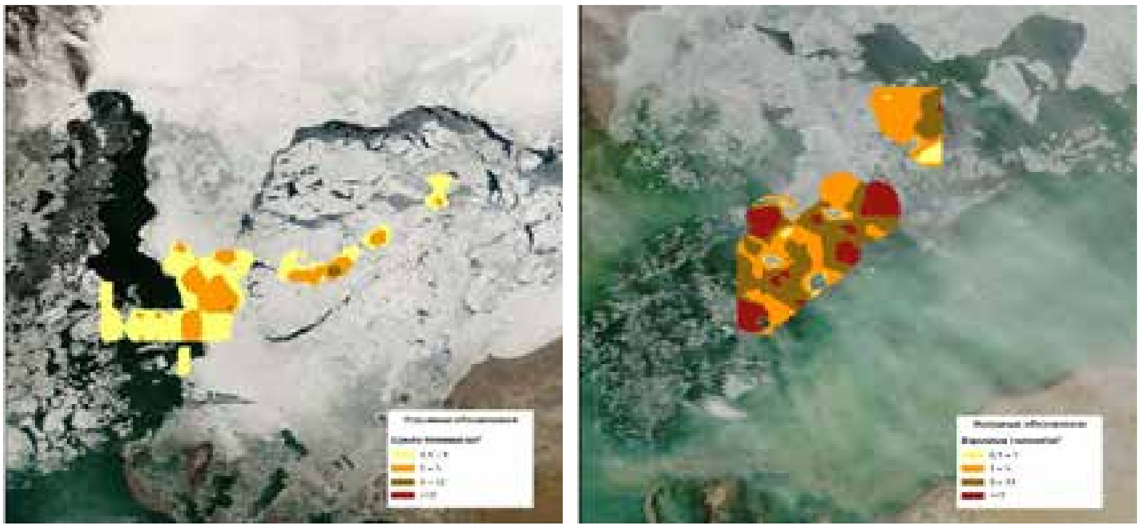
February, 2015 March, 2015

Figure 11.1.7 Preliminary schematic routes of aerial surveys in the North-East Caspian Sea in various periods

All information was recorded on video cameras, which allowed the Company to process the acquired data in office conditions. A careful review of each photograph taken during a particular flight helped to calculate the number of single adult seals (without pups), single pups, "mother-pup" pairs and white-tailed eagles, which are the natural enemies of seals during the breeding period. Such data was used to identify the density of animals' locations and their plotting on the index map in accordance with the nature of their distribution on ice (Figure 11.1.8). The information was used to plan icebreaker routes for supply of equipment, fuel and products to Kashagan.

In 2014-2016, icebreakers made 60 trips between the Bautino supply base and Kashagan field. 4,536 encounters with Caspian seas were recorded. In the same years, success of route planning was assessed by registering all pups within 150 m range from each side of the icebreakers along their route.

During winter navigation in 2014-2016, the



February, 2015 March, 2015

Figure 11.1.8 Maps of animals' distribution with indexed density areas for seal distribution along assumed icebreaker routes level of impact on the Caspian seal population was identified. Its results are presented in Table 11.1.4 and Figure 11.1.9. Preliminary overflights and planning of icebreaker routes contributed in minimization of impact on Caspian seals staying on the ice field during the reproductive period.

The processed materials for 2005-2016 were used as the basis for analysis of changes in the level of impact on the Caspian seal population during the pupping and pups' feeding periods, at various times during the winter navigation of all icebreakers. The analytial results allow to conclude the following:

- The number of "minor" and "medium" impacts of icebreakers on seals varies in different navigation periods, and this is explained by the fact that every year the ice conditions are different as compared to the previous years (no low temperatures, strong winds and water areas covered with ice).
- "Major" cases of impact are recorded in the pupping and pups' feeding periods (the first 20 days of February), with their significant decrease by the end of icebreakers navigation.

Analysis of dynamics of icebreaker encounters

Table 11.1-4 Assessment of icebreakers' impact on the Caspian seal population during the ice navigation periods in 2014-2016

Years	Level of impact	Navigation period, and total number of icebreaker trips	Total number of recorded encounters with seals	Number of recorded encounters with seals with different impact levels	Percentage of encounters with different levels of impact
2014	Low	6-17 March	2553	2426	95,03
	Average	8 trips*		85	3,33
	Severe			28	1,10
2015	Low	31 January — 13 March	1386	900	64,9
	Average	28 trips		412	29,7
	Severe			74	5,3
2016	Low	26 January — 26 February	597	373	62,5
	Average	24 trips		203	34,0
	Severe			21	3,5

Note: * one trip means movement of an icebreaker along Bautino-Kashagan or Kashagan-Bautino route

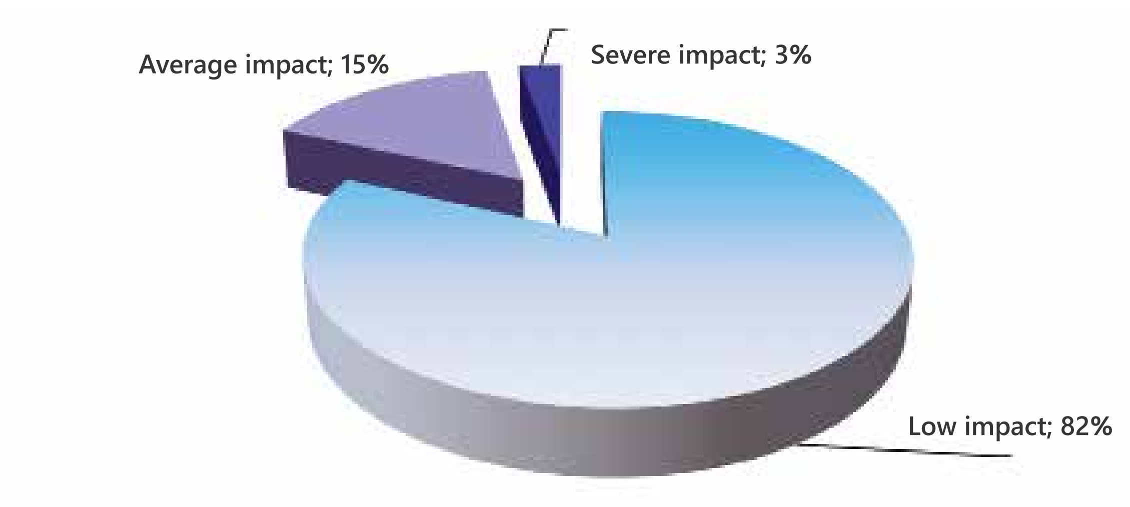


Figure 11.1.9 Ratio of recorded encounters with seals with different levels of impact during winter navigation in 2014-2016.

with seals has shown that the number of encounters increases at the beginning of winter navigation (the end of January and the beginning of February, during pupping and pups' feeding periods), reaching its maximum on 11-12 February. Then it decreases sharply because during this period large spaces of open water appeared and it allowed the icebreakers to bypass the areas of seals concentration.

Speed analyses makes it possible to monitor dependence of icebreaker's movements on the level of impact on seals. Thus, during icebreaking navigation in 2014-2016, in total 123 cases of "major" impact were recorded including 85 cases in the period 6-13 February — during the active pupping and pups' feeding seasons. Table 11.1-5 shows the dependence of the level of "major" impact on icebreaker speed under different visibility conditions.

The acquired data indicates that in majority of cases (81-85.7%), a major impact of icebreakers on seals was registered at speeds exceeding 3.5 knots (1 knot = 1.852 km/h). At night, only 32.1-33.3% of major impact cases were recorded, while some of them were registered under thick fog conditions (8.1-28.6%). At speed below 3.5 knots, 19 cases of major impact were recorded (for the 3 periods of winter navigation).

It is important to note that practically in all cases when icebreakers moved at the speed above 3.5 knots, captains made attempts to reduce the speed in order to allow more time for requisiteand correctly selected manoeuvres and to avoid collision with seals.

11.1.2 Proposals and measures to minimize a negative impact of aerial surveys and icebreakers on the Caspian seal population during pupping and pups' feeding periods

Proposals to mitigate the impact on pup rookeries

- Perform annual assessment of the seal breeding period, including the start, peak and the end periods; identify the periods of mass pupping (when about 70 — 90% of pups are born). Approximately, this is the period from 28 January to 15 February, and it can be 5-10 days earlier or later every year.
- Perform annual environmental monitoring of the population condition, not only from vessels, but also during aerial observations with involvement of trained observers to identify the areas with pupping seals concentrations during mass pupping period.
- Improve the timing and routes of icebreakers given the areas of mass pupping. If possible, restrict or minimize the movement of icebreakers through the pupping grounds from the beginning to the end of mass pupping plus five days thereafter.
- Minimize impact of icebreakers and other vessels on seal population. For this purpose, it is necessary to change navigation routes to ensure bypass of pupping grounds.
- Prohibit movement of vessels through the pupping grounds in red, orange and yellow zones during night hours (see Table 11.1.1 above); allow the traffic in the green zone at the speed of up to 3 knots.
- Create and plot on maps seasonal protected zones in the ice cover areas with significant seal concentrations; develop a flexible definition of temporarily protected areas which would allow to change the borders based on annual shifting of pup rookeries,

Table 11.1-5 Dependence of the level of "major" impact on icebreaker speed under different visibility conditions

Years	Total major impact cases	Number of cases occurring at the speed in excess of 3.5 knots	%-ratio	Number of cases at the speed in excess of 3.5 knots during night hours	%-ratio	Number of cases occurring at the speed in excess of 3.5 knots during thick fog	%-ratio
2014	28	24	85,7	9	32,1	7	25,0
2015	74	63	85,1	25	33,8	6	8,1
2016	21	17	81,0	7	33,3	6	28,6
Total	**123**	**85**	**69,1**	**41**	**33,3**	**19**	**15,4**

depending on the condition of ice cover.

Measures to mitigate the impact of icebreakers and vessels on seals

1. Planning of icebreaker routes:

- It is necessary to arrange special overflights in order to identify the location and borders of Caspian seal breeding grounds prior to the first trip of the icebreaker with observers on-board, taking into account the time required to process the information.

- The information of area locations and warnings regarding breeding seals shall be provided in a processed format; aerial survey results shall be presented in the form of a figure with plotted routes and fixed points of seals encounter; aerial survey and icebreaker observation data shall be consolidated and plotted on the ice map with the relevant index and colour code. If the data is presented in this way, the vessel's crew and observers can ensure efficient planning of routes, avoiding the warning zones, if navigation restrictions allow to do so.

- It is necessary to establish a system for data exchange between groups of icebreaker observers. For this purpose, prior to commencement of winter navigation, the email addresses of all icebreakers shall be available for subsequent transmission of tracks and route points indicating encounters with seals after completion of every trip along the route.

AVAILABLE DATA FROM PREVIOUS TRIPS AND THE LAST TRIP WILL ALLOW THE ICEBREAKER WITH OBSERVERS ON-BOARD TO BYPASS THE LOCATIONS OF SEAL MASS CONCENTRATIONS.

- Every year, at the beginning of January, before the start of the Caspian seal breeding season, vessel crews shall receive information/instructions outlining specific sensitivity of breeding seals.

- Planned routes determined on the basis of aerial surveys results shall be preferably provided in the form of GPS-tracks (a route with indication of angular coordinates) in a certain format. A track can be used in icebreaker navigation devices and also in the equipment of seal observers.

- In order to ensure efficient planning of routes, the consolidated data from aerial surveys and icebreaker observations shall be plotted immediately onto the maps and updated after each trip and aerial survey. The resulting information shall be plotted onto accurate ice maps.

- All icebreakers operating during winter navigation shall follow planned route corridors till ice conditions change and receipt of another recommended route based on the results of an aerial survey.

- Trips shall be planned in a way to ensure movement though recorded seal grounds in the period from 15 January to 15 March during the daytime.

- Thermal cameras and illuminators on the icebreakers/vessels are important equipment, therefore, they shall bekept in a working condition.

- Broken ice fields shall be used for route, thus increasing the movement of icebreakers in open waters. However, permitted depths for vessel movement shall be taken into account.

2. On-board of icebreakers and vessels:

- Observers shall be provided with the results of aerial observations as soon as possible.

- Observers shall have a free access to cartographic materials provided by the ice department and logistics department regarding locations of breeding seals concentrations.

- Icebreaker captains shall comply with regulated speed in accordance with indexation and the relevant colour code of zones warning about breeding seals based on aerial surveys results.

- The vessel captain shall be informed immediately of seals discovered on the ice along the icebreaker route and be given a clear indication of their location to enable a timely and accurate manoeuvre.
- During a left or a right manoeuvre, the situation on the opposite side of the vessel shall be taken into account. When manoeuvring bypass to the left, it is necessary to be sure that there are no seals on the right side of the vessel or they stay at a safe distance from the vessel. Information shall be exchanged between observers and the captain on a continuous basis along the entire route.
- Required but permissible manoeuvres shall be taken when seals and pups are identified along the route of the vessel. Icebreakers shall move at least at 150 m distance from breeding seals and pups.
- In case of extreme necessity, a vessel shall be stopped to ensure a safe bypass of seals. If bypass is not possible such stop time shall be used to allow animals to move at a safer distance from the icebreaker.
- During crossing the seals breeding areas at night, it is necessary to mobilised the entire observers' team to the captain's bridge.

Conclusions

Aerial and icebreakers surveys made it possible to determine the Caspian seal abundance, develop proposals and measures to mitigate icebreaker's impact on the Caspian seal population during pupping and pups feeding periods; and make the following conclusions:

- Caspian seal abundance keeps falling. During 2005-2008 period, detailed surveys were performed to assess annual birth rates and the number of adult seals on the ice. Birth rates in 2005 and 2006 were approximately 21,000 and 17,000 species respectively and then fell sharply in 2007 and 2008 to about 6,000 and 7,000. The total number of breeding and non-breeding seals across the entire Caspian Sea cannot be calculated accurately. The tentative numbers were estimated on the basis of annual birth rates with use of a dynamic model. In 2005, the total population of females was 55,000 species, while the whole population of seals was double higher (110,000 species). Sharp decrease in the number of pups, and subsequently, fertile females, since 2006 is an evidence that decrease in the population currently significantly exceeds 4% on average per year over the last 50 years. In the period of 2005 – 2008, the number of newborns fell by 60%, while the number of adult seals concentrated on ice fell by 30%.

- Improved methods of statistical analysis indicate higher estimate numbers for reproduction of the Caspian seal population, however, they do not have impact on the previous conclusions regarding the status of the population and do not eliminate the grounds for concern on seals' wellbeing. Furthermore, another significant drop in seals reproduction recorded in 2012 (the year of the last aerial survey), in Kazakhstan Sector of the Caspian Sea gives even more cause for concern, because the fertility of the population is determined by some biological factors and the long-term stability of the Caspian seal population can be low. These biological factors can be related to availability and quality of food, introduced species or other changes in the Caspian Sea ecosystem.

- When identifying the reasons for decrease in seal abundance, it is important to distinguish between local, short-term factors (ice cover, the weather and food) and large-scale, long-term factors (mortality, changes in the food chain, pollution and climate change), which have impact on the annual reproduction of the population.

- Seasonal variability, and consequently, unpredictability of pups' occurrence in the icebreaker corridor are related to the type of ice formed at the end of January and the beginning of February. It is ice availability that determines the grounds suitable for pupping. The most vulnerable are mothers with pups in the icebreaker corridors.

NCOC N.V. REALIZES ITS SHARE OF RESPONSIBILITY IN PROTECTION OF THE CASPIAN SEAL. THUS, IT HAS INITIATED LONG-TERM SURVEYS AND COMPLIES WITH RECOMMENDATIONS TO MINIMIZE THE IMPACT OF THE VESSELS MOVEMENT ON THE SEALS.

The recommendations were developed by international experts based on results of multiyear surveys from icebreakers, and then reviewed by the Company production management and icebreaker crews, with majority of recommendations approved by them.

11.2. Distribution and abundance of Caspian seals during the ice-free period based on the survey data aquired with use of a scientific-survey vessel

Survey methodology

Surveys of the Caspian seals during the ice-free period (spring, summer and autumn) were organised by NCOC N.V. as part of its monitoring surveys (environmental monitoring) from scientific-survey vessels, starting from autumn 2012. These surveys covered the offshore fields Kashagan, Aktote, Kairan, Kalamkas-sea and the Oil field pipeline route.

Seal counting was conducted at each sampling station continuously during 30 minutes. The highest position on the vessel was chosen to ensure all-round view of the water surface. Observations were made with 10x and 30x binoculars at 500 m range. When single specimens or groups of seals were noted, the information was recorded with a digital dictaphone. The number of specimens, the reason for staying in the area, and behavioural reaction to moving and anchored survey vessels and support vessels was noted. When possible, pictures of seals were taken with a digital camera (70-300 mm lens or a 20x zoom) and then reviewed in more detail with computer.

During the survey period from autumn 2012 till autumn 2016, in total 2,245 hours of visual observations were spent at 4,489 sample stations. 1,427 Caspian seals were registered on the sea surface in the water area under survey (Table 11.2-1). Dead seals were also recorded, including 11 dead adult seals and 1 dead sivar.

11.2.1 Survey result

Distribution and abundance of the Caspian seals according to monitoring surveys

This section provides assessment of distribution and abundance of seals in the open water, annual and seasonal dynamics, and impact of offshore facilities construction on these variables. Kashagan, Aktote and Kairan fields cover the whole Contract Area (sampling stations — levels 1; 2; and 3).

During the warm period, seals are widespread across the entire Caspian Sea and do not form any major concentrations [Strautman, 1984]. Satellite data allowing the tracking of tagged seals (see Section 11.3) indicated that the north-eastern part of the Caspian Sea (from the Komsomolets Bay to the Zhaiyk River (Ural) estuary and the coastal migration corridor are important feeding, resting and migration grounds from October till ice formation [Dmitriyeva, 2012, CISS, 2012-2013].

During monitoring in 2012-2016 along the Oil field pipeline route, the observations were performed in the 4,000 m corridor from D island to the shore. The main impact on the seal habitat in this area is caused by significant drop of the sea depth closer to the shore and surging events. The seals in this area are mainly encountered in the deeper southern section of the Oil field pipeline route. 2 specimens/km^2 were observed as maximum with the average rate 0.2 specimens/km^2 for the entire survey period. In spring and summer, seals were observed less often, 0.1 — 0.3 specimens/km^2. In autumn 2014–2016, abundance increased to 0.4–1.1 specimens/km^2 (Figure 11.2.1).

Table 11.2-1 Number of stations and registered seals, by years and seasons

Year	Spring			Summer			Autumn			Total	
	Dates	Stations	Seals	Dates	Stations	Seals	Dates	Stations	Seals	Stations	Seals
2012	-	-	-	-	-	-	12.11 - 01.12	78	132	78	132
2013	05.04 - 30.05	383	234	15.06 - 27.07	389	135	03.10 - 04.11	411	190	1183	559
2014	03.04 - 25.05	404	90	14.06 - 05.08	402	68	22.09 - 03.11	398	110	1204	268
2015	15.04 - 27.05	431	81	25.06 - 20.08	426	99	20.09 - 30.10	431	127	1288	307
2016	15.04 - 14.05	243	49	25.06 - 24.07	240	53	20.09 - 19.10	253	69	736	171
Total	**-**	**1461**	**454**	**-**	**1457**	**355**	**-**	**1571**	**628**	**4489**	**1437**

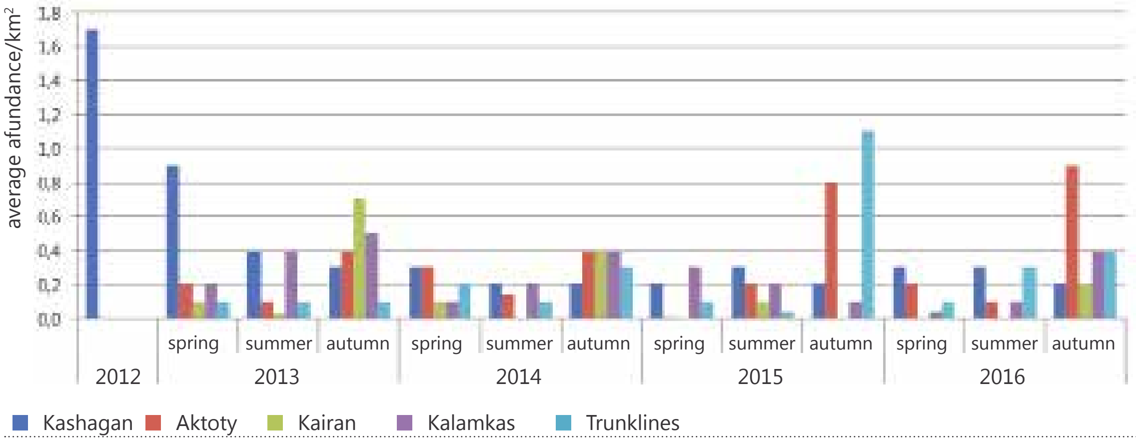


Figure 11.2.1 Average seal abundance by offshore facilities in 2012-2016

Kashagan field water area saw a significant drop in seal abundance from autumn 2012 to autumn 2013, from 1.7 to 0.3 specimens/km^2. In subsequent years, their abundance in spring and summer did not exceed 0.3 specimens/km^2, while in autumn the abundance was 0.2 specimens/km^2. The maximum observed seals were up to 6 specimens/km^2, while the average value for the entire survey period was 0.4 specimens/km^2.

Aktote field saw seasonal changes in abundance from spring to autumn with decrease in the summer period and a significant increase in autumn, and also an increase in abundance every autumn, from 0.4 in 2013 to 0.9 specimens/km^2 in 2016. In spring, average abundance was 0.2–0.3 specimens/km^2, and in summer 0.1 0.2 specimens/km^2. Abundance was very low with 0.01 specimens/km^2 in spring 2015 due to the low water level, with the average depth of 1.1 m [Environmental monitoring report, spring 2015]. The highest abundance was 5 specimens/km^2, while the average value for the entire survey period was 0.3 specimens/km^2.

As opposed to other locations, no seals were observed at Kairan in 2014–2016 (Figure 11.2.1). The seals' habitat in the shallow coastal zone is significantly affected by surges. Average abundance in spring and summer did not exceed 0.1 specimens/km^2, while in autumn it was 0.2–0.7 specimens/km^2. The drop in autumn abundance from 0.7 specimens/km^2 in 2013 to 0.2 specimens/km^2 in 2016 could be caused by the Caspian Sea level drop by 0.4 m in the period 2012– 2016 (Figure 2.4). Maximum abundance of 2 specimens/km^2 was observed in autumn, while average long-term abundance amounted to 0.1 specimens/km^2.

In 2013, 2014 and 2016, Kalamkas also saw an increase in seal density in open waters from spring to autumn. Their average abundance increased from 0.04-0.2 specimens/km^2 to 0.4-0.5 specimens/km^2 in autumn. Opposite situation was observed in 2015, i.e. spring abundance of 0.4 specimens/km^2 had decreased to 0.1 specimens/km^2 in autumn. Maximum abundance at Kalamkas was 4 specimens/km^2, while the long-term average value was 0.2 specimens/km^2. These materials characterise the abundance and distribution of seals in water areas under survey as shown in Table 1, and can differ significantly from the data for earlier (March) and later (November–December) periods.

Thus, according to Company survey [Environmental monitoring reports, 2012-2016], the average seal abundance varied from 0.03 to 1.7 specimens/km^2 with average long-term variables 0.1–0.4 specimens/km^2. According to estimation in other references, seal density in the open waters of the North-East Caspian Sea amounts to 0.5-1.5 specimens/km^2 [Mangistau Oblast Atlas, 2010].

Seal ratio in age groups in spring and summer

Two age groups were identified during spring and summer surveys: adult and young seals — sivars, which differ by their body size and colouring. In 2016, no age groups were recorded.

Figure 11.2.2 Young Caspian seal — sivar

At the age of 5-6 weeks, new-born white-coat seals that have fully changed their infant fur are called sivars. At this stage of their development, they start an independent way life in the open water and join the general livestock. The sivar's short hair is dark grey on the back and light-grey on the belly (Figure 11.2.2). The spots on the top, if they appear, are not always visiable. The vast majority of adult specimens tend to moult, especially on their backs (Figure 11.2.3).

Along the Oil field pipeline route, sivars were observed only in summer 2013 in a deeper section (section NP 01), with their ratio to adults 3:1. In other spring and summer seasons 2014 and 2015, and spring 2013, only adult seals were recorded.

At Kashagan, young and adult seals were present in all years under survey (Figure 11.2.4). In 2013, in both seasons adult specimens were dominant, with the ratio in spring 1:4, and 1:2 in summer. In spring 2014, the quantity of seals across the age groups was 1:1, while in summer it far in favour of sivars 4:1. In 2015, adults were predominant in spring with the ratio1:4, while in summer young seals prevailed with ratio 5:1.

At Aktote field, in both seasons, young specimens were only observed in 2015. In spring, the ratio of seals was 1:1, while in summer adults dominated with ratio 1:6. In summer 2013, the quantity of young seals exceeded the adults 2:1. In spring 2013 and both seasons 2014, only adult seals were registered.

Figure 11.2.3 Adult Caspian seal

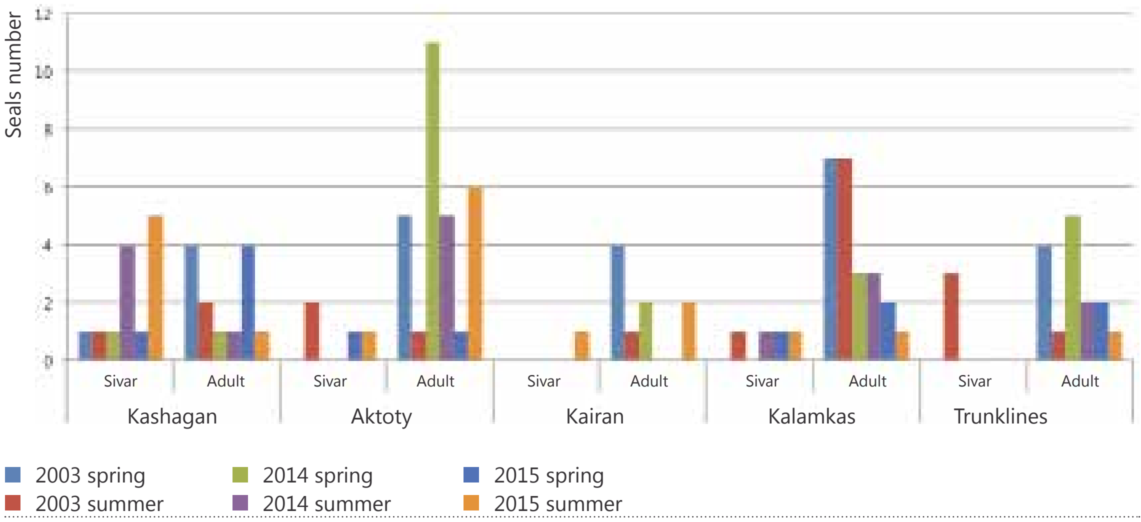


Figure 11.2.4 Ratio of young and adult seals in spring and summer seasons at offshore facilities in 2013-2015

At Kairan, in summer 2014 and spring 2015, there were no seals. Young specimens with ratio 1:2 were observed in summer 2015. In all other seasons, only adult specimens were observed.

At Kalamkas field, sivars were absent in spring 2013-2014, but in both years they were observed in ratios 1:7 and 1:3. In spring and summer 2015, young and adult specimens were observed in ratios 1:2 and 1:1, respectively.

The lack of seals of both groups in summer 2014 and spring 2015 at Kairan field can relate to the low sea level or its higher temperature. Such unfavourable conditions for seals occur during extened surge events caused by strong and continuous winds from the south-east, east and north-east. According to the survey, young seals prefer to stay at depths of more than 3 m, and were met most frequently and in higher numbers in Kashagan and Kalamkas-sea areas and the start section of the Oil field pipeline. Seals are observed rarely in the shallow waters at Kairan and Aktote fields in spring and summer periods. In total, 39 adults and 6 young seals were registered in 2013-2015 at the level 1 monitoring stations at the above fields.

Impact of the Company's offshore facilities on distribution and abundance of seals in the Contract Areas

Seals that do not leave the North Caspian Sea in summer are usually sick or weak animals. Therefore, they do not take part in trophic migration and, as a rule, keep close to the islands. In Russian waters Malyi Zhemchuzhny island serves as a recreation zone for the Caspian seals [Khuraskin, 2001].

The surveys have shown that the artificial islands also attract seals. Under storm weather conditions in the shallow areas, they are unable to dive to depths so take shelter from the leeward side of the island and protection barriers where the waves are practically absent. It is also possible that the feed stock is richer at the artificial islands similar to the natural islands.

The above is confirmed by monitoring results. In spring and summer seasons in 2013–2016, Kashagan saw a higher density of seals around the artificial islands, at level 1 monitoring stations. In autumn, density increases with further distance from the artificial islands (Figure 11.2.5), probably due to seals returning to their wintering grounds.

At the standalone islands at Aktote and Kairan fields, a high number of seals was observed more often far from the artificial islands, in a natural environment, which can be explained by shallow water around the artificial islands.

Man-caused factors resulted from the operations in the Company's Contract Areas (presence of artificial islands, vessel traffic and noise) had no

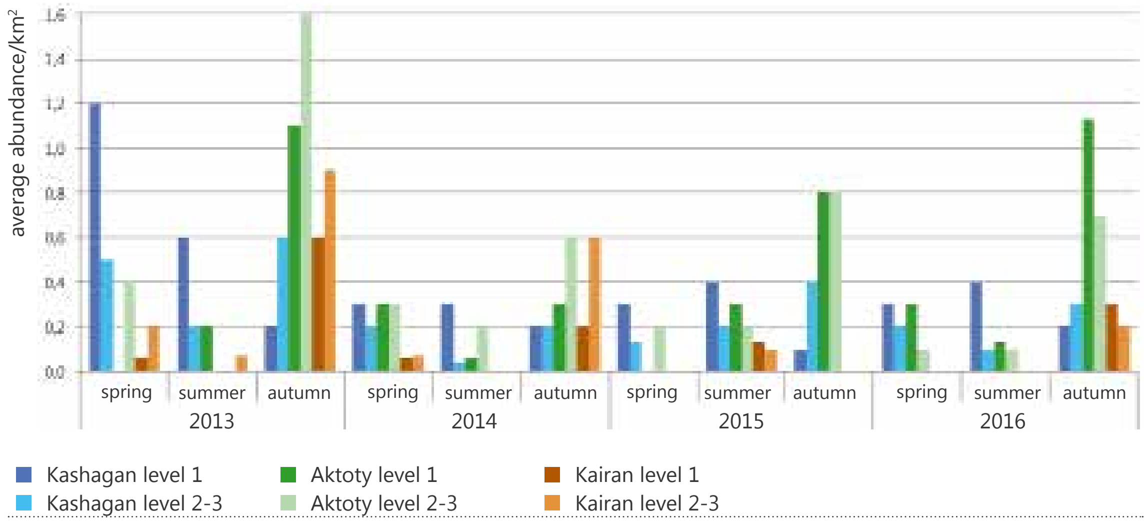


Figure 11.2.5 Dynamics of distribution and density of seal habitat at artificial islands (level 1 monitoring) and at a distance from them (levels 2 and 3 monitoring)

significant impact on habitat and changes of seal abundance in the water areas under survey. The identified changes in seal density at the surveyed fields (Figure 11.2.5) are probably related to the seasonal changes in the feed stock, depth of the sea and water temperature, but not operational activities.

11.3 Monitoring of the Caspian seals migration using remote measurement method (seal tagging)

The Caspian seal is a prominent representative of the Caspian Sea wildlife. The surveyof its behaviour is of scientific and applied significance. Knowledge of seal migration routes makes it possible to recommend to the oil and gas industry and marine shipping the locations for accommodation of their operational facilities and organise their activities with minimum risk for these animals.

Satellite tagging is widely used all over the world to surveyhabitats and migration routes for sea mammals (seals, fur seals and sea lions).

There is an opinion that the "Caspian seal" species is presented by one population distributed across the entire Caspian Sea and it migrates every season between the northern and southern sections of the habitat. It is known that the breeding population of seals uses the ice in the North Caspian Sea for pupping. Once the ice melts, the seals, except for sivars (current year pups) collect on the island for the annual moulting. It is assumed that after this all seals (young and adults) migrate across the entire Caspian Sea to feeding grounds. However, not much is known about the seals' migration routes and the exact location of their feeding grounds. Therefore, one of the objectives of the survey was to establish whether the Caspian seals are subject to extensive seasonal migrations to various feeding grounds ("nomadic" behaviour) or choose a "home" location of the sea and during the year they move and feed mainly within its range ("settled" behaviour), or whether they combine these types of feeding behaviour at different times.

As a whole, seal migration has not been sufficiently studied. For this reason, NCOC N.V. conducted a seals' survey with use of satellite tagging. This allowed acquiring new data on the behaviour and ecology of the Caspian seals. Tagging of seals with satellite sensors operating in Argos system was done in various seasons of the year.

For example, it was established that the nature of autumn-winter migration was more complex. Previously it was assumed that once seals had moved to the north before winter, they stayed in the northern part of the Caspian Sea for the entire ice season. However, tagging of seals allowed to identify their dynamic behaviour when they entered and left the area covered with ice a number of times and moved to southern areas probably for feeding. This new information is very important in surveyof this species [CISS, 2010-2013].

It is worth noting that there are not many publications describing the Caspian seals surveywith use of satellite remote measurements [Dmitriyeva, 2012]. It is also known that in the period 1998–2001, a surveywas performed by a Japanese-Russian group headed by N. Miyazaki (Institute of Oceanic Survey of Tokyo University). Seven seals caught at the Malyi Zhemchuzhny island had been tagged. However, there is no information available on the results of this survey.

This review is based on the results of surveys performed by Simon Goodman (Institute of Integrated and Comparative Biology, Leeds University, UK) and Liliya Dmitriyeva (St. Petersburg Society of Natural Scientists, Russia) under contract with NCOC N.V. The results were published in reports and an article [Dmitriyeva, 2012; CISS, 2008-2013].

The information received of the seals' choice of habitats, their migration behaviour and diving allows to assess the danger for the seals caused by oil production operations in the Caspian Sea shelf and by shipping, especially in the winter period.

Materials and methodology

In 2008-2009, the Consortium organised a pilot survey to test suitability of the satellite remote measuring method to surveyCaspian seal migration routes [CISS, 2008-2009]. The preliminary data was used as the basis for planning further stages of survey.

The SMRU SRDL, WC-SPOT5 and WC-SPLAS sensors of Wildlife Computer company operating in Argos satellite system (https://argos-system.cls.fr) were used to track the coordinates of the tagged seals. Monitoring of seals' location was carried out every day through Argos website.

Satellite data on the distribution of seals was entered once a week into a database (archive) and analysed in detail at the end of the survey period. At the final survey stage, the information received from all tags was decoded using the software Data Analysis Package of Wildlife Computers company. This software generates a database on all seals' locations based on the data received from the tags and determines the accuracy of observations by filtering dual location signals.

The data regarding the movement of tagged seals, which was limited by a 95% contour of probable density with fixed Kernel density, was plotted on the maps prepared with use of ArcMap10 and Geospatial Modelling Environment software. The data on the seals' diving and resurfacing was analysed with software used for processing "R" statistics data.

The dimensions of the tag (excluding the antenna) for marine mammals are from 1.5x3x5 cm to 4x6x10 cm depending on sensors fitted and battery size. The mass of the tag was almost negligible as compared to the seal body mass.

To enable tagging and the generation of physiological data, seals were caught using special shore nets and nets attached to boats. The seals selected for tagging were then placed in net-stretchers for tagging and sampling (blood) to establish their health condition. All seals were released back into the water as soon as tagging was completed.

DURING TAGGING OF THE SEALS, THEIR GENDER, SIZE, BODY MASS AND AGE (IMMATURE JUVENILE/ MATURE ADULT) WERE RECORDED.

Helicopter overflights were organised to identify locations of seals 'rookeries prior to tagging.

During the survey it was planned to tag up to 20 seals per year. Tagging was envisaged in the period immediately after moulting (April- the beginning of May) and in November. The data available at that time allowed to assume that those were the periods when seals were most available for tagging because they formed large concentrations along the Kazakhstan coastline, while during all other periods the seals were more widely spread across the entire sea area. Moreover, the tagging of seals in spring and autumn had higher chances to collect the data on their migrations in spring-summer and autumn-winter periods.

In November 2008, five WC SPOT satellite tags and 2 SMRU SRDL tags were fitted on 7 seals (5 young seals and 2 adult specimens). They were fixed on the animal's neck with a standard method by sticking with a special epoxide glue. In 2009 and in subsequent years the tags were fixed on the seals' heads. The reason for that was seal's behaviour during diving and staying on the water surface and more reliable fixing of sensors ensuring longer and more stable signals from sensors (Figure 11.3.1).

The SMRU SRDL satellite tags used in 2008-2009 survey were too large for their fixing on the heads of the Caspian seals, therefore, since 2010-2012 very small tags had been used (Wildlife Computers company, WC-SPOT5 and WC-SPLASH), which identified the location of the animal and the depths of its diving (Table 11.3-1).

In 2008, pilot tagging took place on the Rybachii island. The weight of the two females tagged was 60-70 kg (with length of 120-126 cm) and the five young specimens — 15-24 kg (length — 79-90 cm). In November 2009 and October 2010, the seals were tagged in the Kendirli Bay (Figure 11.3.2).

2010 saw the start of a full-scale survey of the Caspian Sea seals with satellite remote measuring based on results received in two pilot surveys (2008-2009 and 2009-2010). 22 seals tagged in 2010, included 20 females and 2 males; with their body length varying from 102 cm to 127 cm.

In April 2011, the seals tagging area was preliminarily identified by helicopter and the animals were caught in the Komsomolets bay on the Durnev islands (Figure 11.3.3). 47 seals were caught and measured. 33 seals were tagged including 9 females and 24 males. In October 2012, 22 seals were caught and measures, with tags fixed on 15 seals — 9 females and 6 males. Their body length varied from 108 cm to 135 cm.

The seal tagging performed in 2012 was the continuation of two pilot projects (2008-2009 and 2009-2010) and two full-scale surveys (2010-2011 and 2011-2012). Their purpose was to get additional data on movements of the Caspian seals and use of their habitat in the autumn-winter period.

11.3.1 Survey findings. Seal distribution and migration. Habitats

Scientific surveys included two stages:

- Pilot surveys performed in 2008 and 2009, when satellite remote measuring transmitters were selected according to size, capacity, operating time and the ability to determine diving depth in feeding periods [CISS, 2008-2009; CISS 2009-2010]. Pilot surveys were used as the basis for the start of further large-scale surveys. They allowed to identify locations suitable for catching and tagging seals and testing the working characteristics of satellite tags in order to determine their optimum parameters for Caspian Sea conditions.
- Full-scale surveys of seals migration performed in various seasons in 2010-2012.

Pilot survey

Figure 11.3.1 WC-SPOT5 tags on the head of a seal

Table 11.3-1 Seal tagging details

Year	Tagging location	Number of tags provided by Wildlife Computers, SPOT5 series	Number of tags provided by Satellite Relay Data Logger, SMRU SRDL series	Number of tags provided by Wildlife Computers, SPLASH* series	Maximum tag operating period
2008, November	Seal island, Rybachii Island	5	2	-	Till February 2009
2009, November	Kendirli Bay	5	-	-	Till March 2010
2010, October	Kendirli Bay	11	-	11	Till May 2011
2011, April	Komsomolets Bay, Durnev island	18	-	15	Till April 2012
2012, October	Kendirli Bay	8	-	7k	Till March 2013

Note: **- the sensor provides not only the data on location, but also on diving*

In November 2008, satellite tags were successfully fixed on 7 seals caught on sand banks to the south of Rybachii island (Seals Islands). The tags were operational for three months and allowed to receive the data on movements of the tagged seals (Figure 11.3.4). As a whole, the levels of data returned were a bit lower, while tag losses were higher than expected as compared with results of seals surveys with satellite remote measuring method in other areas in the world.

The data received from the tags indicated that the seals had used five areas in the winter season:

1) Between the Bautino cape and the point to the south of the Seals Islands;

2) To the east of the Seal Islands, between the northern coast of the Mangyshlak peninsula and the Ural Furrow;

3) To the point approximately at 60 km distance from the coast, to the south-west of Bautino/ Fort Shevchenko;

4) To the south along the 50-m isobaths to Aktau;

5) Shallow waters of the North Caspian Sea, between the Komsomolets Bay and northern coastline, and further to the Ural Furrow.

Seal tagging was also performed in 2009 as the continuation of 2008 pilot tagging. The seals were tagged in the Kendirli bay where large concentrations of seals had been previously

Figure 11.3.2 Seals at the Kendirli bay (November 2009)

Figure 11.3.3 Moulting seals on the Durnev islands. Komsomolets bay. April 2011

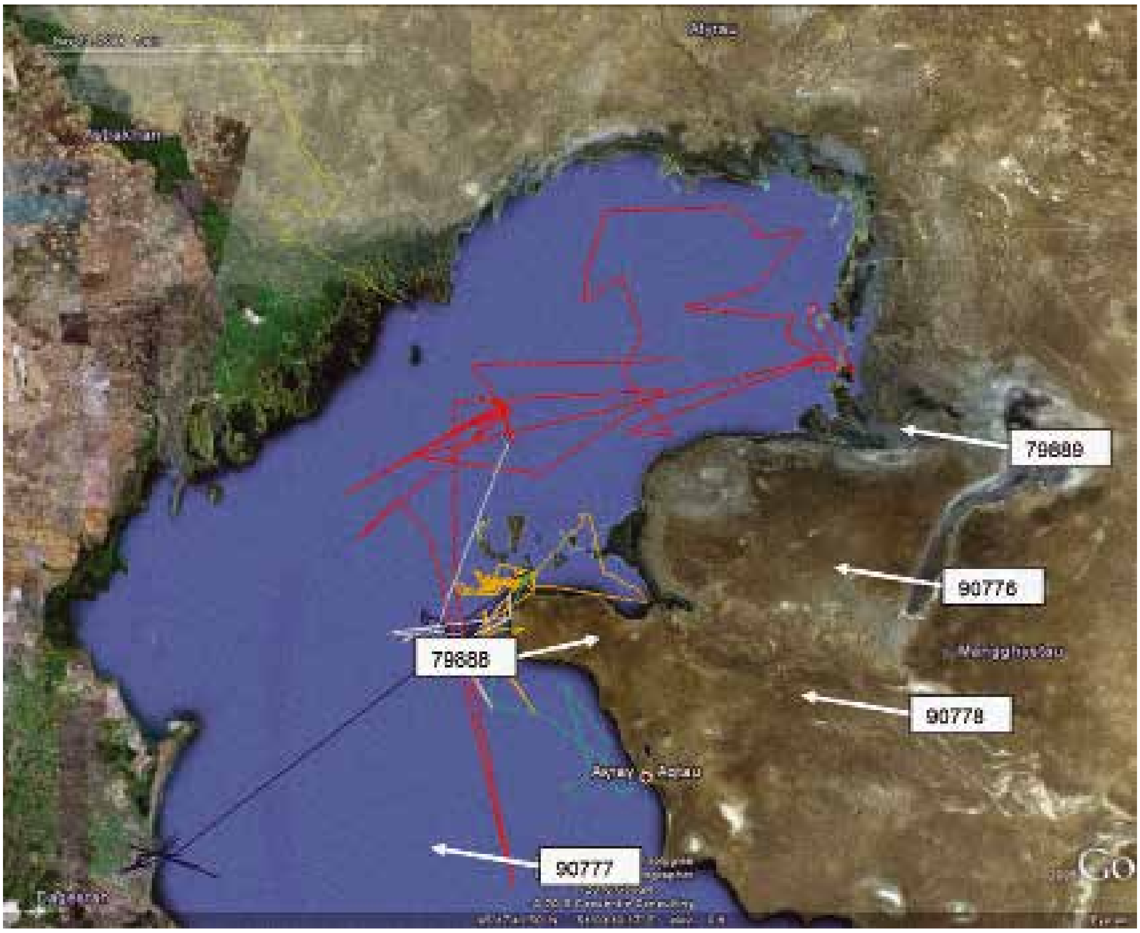


Figure 11.3.4 Full movement tracks of tagged seals, 2008-2009

recorded and where they stayed on land which made an easier access for their catch. Previous tagging methodology was improved and a number of technical issues was resolved. Those issues related to low levels of data returned, thus, the sensors were replaced by smaller tags that were fixed on the animals' heads.

The results of the surveys in 2009 showed that four out of five tagged seals, from the moment they were tagged till the formation of the first ice in the middle of December 2009, stayed at the distance of 50-80 km from rookeries in the Kendirli bay. The area close to the Kendirli bay rookeries seemed to be their important fattening ground. Once the ice cover was formed in the northern section of the Caspian Sea, the seals migrated to the north, covering approximately 350 km in 3-4 days (Figure 11.3.5). Two seals (1 male and 1 female) stayed on the ice during the entire ice period, while two others (1 male and 1 female) made multiple movements further to the ice field alongside with movements for feeding in the southern direction.

One tagged female moved 450 km to the south immediately after tagging to the southern tip of Ogurchinsky island (Turkmenistan). Unfortunately, the contact with the tag was lost on 6 December. Even though the survey was a pilot project aimed at assessment of operating characteristics of the tags, the received data allowed to assess the use of some habitats by the Caspian seals. Specifically, it can be assumed that a migration corridor exists along the Kazakhstan coast from the border with Turkmenistan to Bautino (Figure 11.3.5) and stretching from the coast to the 50-m isobaths. Furthermore, four seal feeding grounds were identified close to the Kendirli bay, Aktau and to the south-west of Bautino. The tags also helped to identify some aspects of individual behaviour.

The tracks of the majority of seals showed that during the fattening period, multiple movements were observed in limited areas of the sea covering approximately 10-20 km^2, which the seals used for feeding, and for resting. Feeding migration lasted from several days to several weeks.

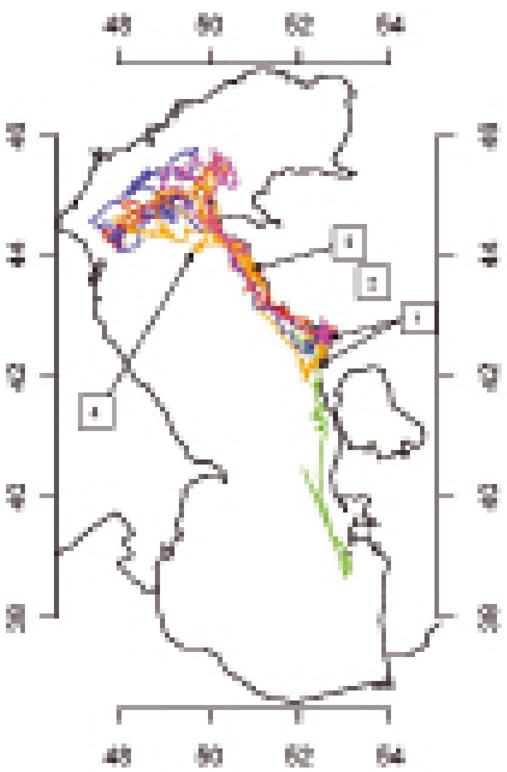
With the start of ice cover formation in the North Caspian Sea, all tagged seals, left the Kendirli bay area in several days. At the end of December, the seals moved to the ice from where they performed regular feeding food migrations, both within the North Caspian Sea area and to the south.

Over the entire survey period, the majority of tagged seals moved at comparable speeds, covering about 1,000 km per month.

Full-scale monitoring survey in 2010-2012

Seals were also tagged in autumn 2010 in the Kendirli bay because of recorded stable concentrations of seals in large numbers and an easy access for their catch. The purpose of tagging the seals in 2010 was to get the information on their habitat, their migration behaviour, their diving depth during feeding and to assess potential dangers of oil production [CISS, 2010-2011, 2011-2012].

Despite the existing individual nature of migration behaviour, in general, the seals can be divided into two main groups according to the time they took to leave the tagging area (Kendirli bay). After tagging, within two weeks, the majority of tagged seals (15 specimens) had moved 300-500 km to the north of the Kendirli bay. The remaining 7 tagged seals stayed at 50-100 km distance from rookeries in Kendirli till the end of December —



Note: The arrows and figures in the squares show potential seal feeding grounds

Figure 11.3.5 Satellite tracks of seal movements in 2009-2010

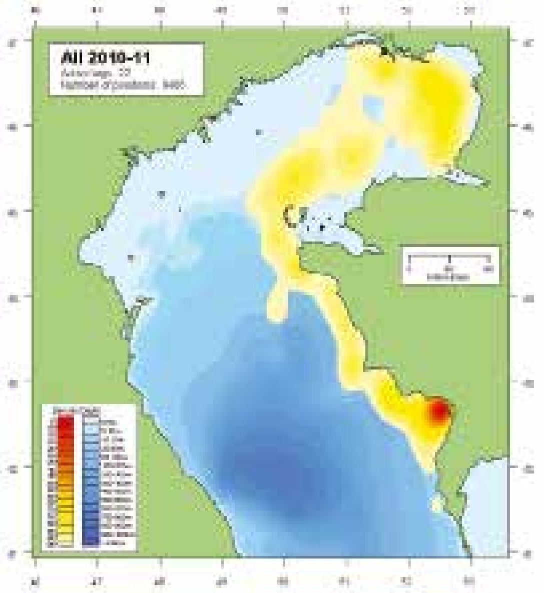


Figure 11.3.6 Habitats of the Caspian seals with a 95% seal density with a fixed kernel. October 2010 — April 2011

beginning of January, leaving to feed in the Kendirli bay and along the coast, and periodically returning to the rookeries.

The migration paths of all seals had a common corridor between the Kazakhstan coast and the 50-m isobaths and extending from the border with Turkmenistan to the Zhaiyk River delta. During the entire autumn period, the seals moved across the shallow water area to the north-east of the Kazakhstan Sector of the Caspian Sea, and then in winter and spring migrated to Russian territorial waters.

Over the entire survey period, the majority of seals demonstrated a similar speed of movement covering the distance 11–46 km per day.

Seal migration from the Middle Caspian Sea area to the north started with formation of ice cover in the North-East Caspian Sea. In December, the tagged seals were in migration process along the Kazakhstan coast (up to 50 km from the coast) from the Kendirli bay to the Seals Islands. The other seals after fattening in the North-East Caspian Sea and the Ural estuary migrated to the south towards the Ural Furrow and Seals Islands. Figure 11.3.6 shows habitats limited by a 95% probable density. It means that in the period October- March, a probability to find a seal in that area is 95%.

In January 2011 with a higher ice cover area, the seals grounds were confined mainly to the south-eastern part of the coast between Seals Islands and the Kendirli bay, while the ice-covered North-East Caspian Sea was characterised by a low density of tagged seals.

In February, the densest groups of immature juveniles were noted in the ice-free coastal area between 42.8° northern latitude (Peschanyi peninsula) and the ice edge (Figure 11.3.7).

In March, with decrease of the ice cover, the tagged seals stayed in areas from the Ural Furrow, Durnev island, Kulaly island and down along the Russian coast, and also along the "migration corridor" in Kazakhstan, where the moulting seals mostly likely migrated following the drifting ice fields.

In spring (April) 2011, the purpose of seal tagging was to get the information about their migration behaviour and use of their habitats in summer and autumn periods.

In April, after moulting, the majority of tagged seals from Durnev island began to move towards the Middle and/or South Caspian Sea, migrating predominantly along the western or eastern coast, where they stayed in fattening grounds

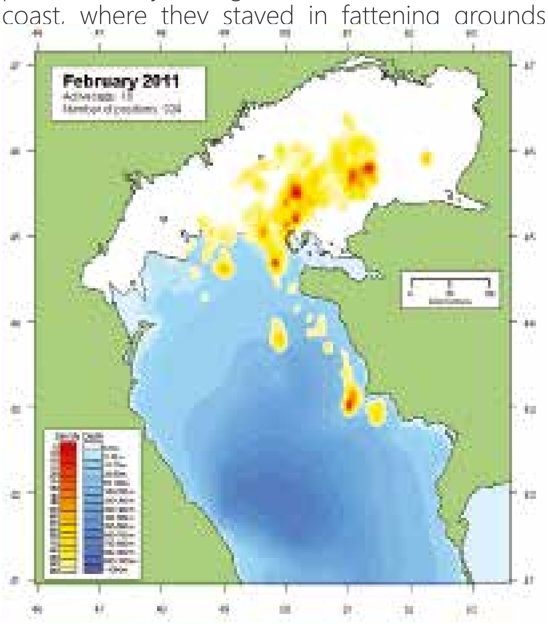


Figure 11.3.7 Habitats of Caspian seals. 95%-density of Caspian seals with a fixed kernel. February 2011. White areas in the North Caspian Sea are the approximate borders of the ice cover based on MODIS satellite images)

from May to October-November. Some tagged seals (40%), never left the North Caspian Sea area (where the water depth did not exceed 20 m). [CISS, 2010-2011].

Ten tagged seals migrated to the South Caspian Sea, four seals moved to the western shore of the Central Caspian Sea — the area between Makhachkala (Russia) and Sumgait (Azerbaijan) with significant increase in the water depth from 20 to 600 m, while the remaining specimens moved along the eastern coast of the North Caspian Sea — the area between the Kendirli bay and the southern border of Kara-Bogas-Gol, where the water depth varies between 50 and 200 m.

The seals that migrated along the eastern coast used the previously established "migration corridor" between the Kazakhstan coast and the 50-m isobaths and extending from the border with Turkmenistan to the Zhaiyk River.

Over the entire survey period, the majority of seals demonstrated a relatively stable speed, covering in the range of 18–58 km per day.

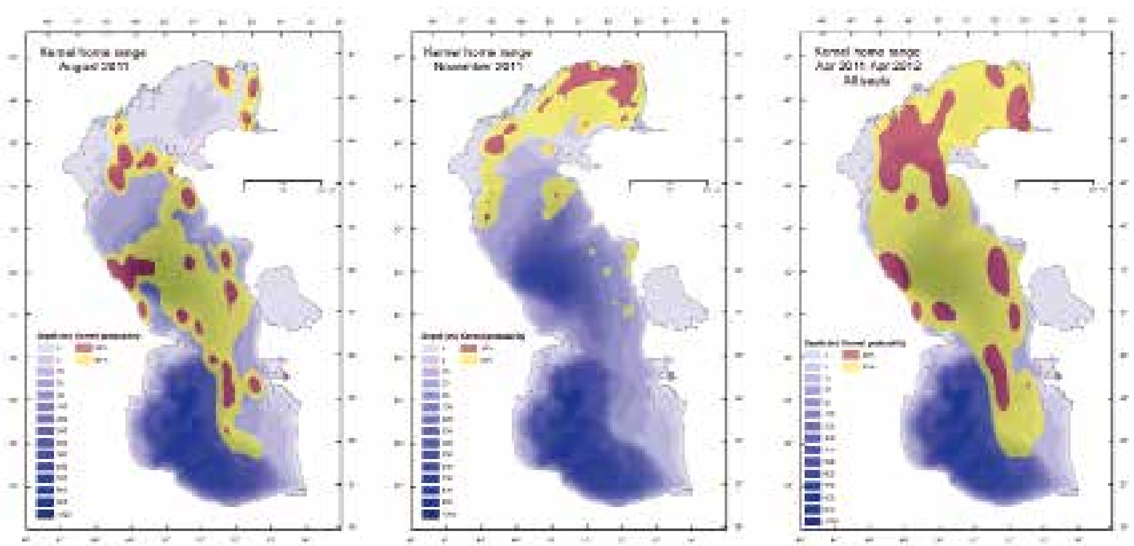
As a whole, the seasonal differences in habitats use can be seen in Figure 11.3.8, showing a density probability of 95% and 50% with a fixed kernel, i.e. the probable density for locations of tagged seals in August and November and for the entire 2011-2012 survey period. A 95% habitat probability means that the probability for a seal to be within that area is 95%.

The total area within the 95% density range for all tagged seals was 248 648 km^2, which was practically the entire area of the North Caspian Sea and the Middle Caspian Sea.

2011-2012 data allowed to determine characteristics of habitats separately for males and females. The area of 95% probable density habitat for males was 229,381 km^2 and was mainly similar to 95% probable density habitat for all tagged seals. While the habitat area for females was only 156,755 km^2 and did not include the central waters of the Middle Caspian Sea with the depth over 200 m.

During the year, the majority of seals spent on average about 10-15% of the day on the sea surface, however, sometimes the time periods used for resting were much longer, for example, in February and March, the time spent on the surface increased to 50-60% or more.

The surveys in 2011-2012 allowed to identify a number of important fattening grounds [CISS, 2011-2012]:



A B C

Figure 11.3.8 Caspian seal habitats confined to a 95% probable density range (shown in yellow) and a 50% probable density range (shown in red). (a)- August 2011; b) November 2011 and c)- for the entire 2011-2012 survey period)

- Seals are registered in the Komsomolets bay and the area extending approximately up to 100 km from the coast line to the north and to the border with Atyrau Oblast between April and November;
- The Zhaiyk River delta (area 80 km from the coast line) — between April and November;
- The Volga River delta — between May and August, and November and December;
- The Ural Furrow area — during the entire survey period between April 2011 and April 2012;
- The western shore (area extending approximately at 100-150 km from the coast line between Makhachkala (Russia) and Sumgait (Azerbaijan) — between April and December;
- the North Caspian Sea — between May and September;
- The eastern coast (area in the North Caspian Sea between the Kendirli bay and the southern border of the Kara-Bogas-Gol bay, extending from the coast approximately to the 200-m isobaths);
- The Kendirli bay in April-June and November;
- The South Caspian Sea, eastern part, at depths 50–400 m — from May to October.

The surveys in 2012-2013 were the third full-scale project to surveythe Caspian seals with satellite remote measuring. It was the continuation of two pilot tugging projects in 2008-2009 and 2009-2010, and two full-scale survey projects in 2010-2011 and 2011-2012 [CISS, 2012-2013].

THE PURPOSE OF THESE SURVEYS WAS TO ESTABLISH SEAL MIGRATION ROUTES IN THE AUTUMN-WINTER PERIOD.

In October 2012, field works were performed to tag seals in the Kendirli bay (15 tagged seals). During the feeding period eleven seals used the "migration corridor" for multiple movements between the southern and northern parts of the Caspian Sea. Such corridor extended from the border with Turkmenistan to the Zhaiyk River delta. Four seals had a settled life-style taking only short feeding migrations at the Kendirli peninsula. The daily average distance covered by them was in the range of 29-41 km, with speed depending on the level of activity of the various specimens.

During the ice formation period and the entire ice period (from the end of November till March), the seals actively used the western and eastern parts of the North Caspian Sea, its central water area and also the Ural Furrow area (between December and March).

Thus, during the survey period from October 2012 till March 2013, the seals regularly used the Kendirli bay and "migration corridor." The majority of tagged seals actively migrated over significant distances in the North Caspian Sea, covering 2,300–5 500 km over the entire period. It was a trans-border migration, crossing the Russian and Kazakhstan territory.

The seals used the shallow waters of the North-East Caspian Sea from the Komsomolets bay to the Zhaiyk River delta for movement, fattening and resting from the end of November till the end of December [Dmitriyeva, 2012; CISS, 2012-2013].

The habitat area for all tagged seals during the 2012-2013 survey period confined to a 95% probable density area with a fixed kernel was 69 906 km^2. It covered the North Caspian Sea and the coastal areas of the North Caspian Sea (Figure 11.3.9). This Figure shows the areas with 95% and 50% probable density with a fixed kernel for the period from October 2012 till March 2013 for all tagged seals.

The surveys in 2012-2013 showed that seals demonstrated approximately 95% level of activity between October and the end of January with very little rest. Activity levels fell on the beginning of February, while the rest time increased to 50-100% and remained at that level till the end of the survey. Most likely, the seals stayed on the ice during this period, which in case of adults can be due to breeding.

11.3.2 Results of the analysis of seal resurfacing and diving data

In autumn 2010, for the first time seals were

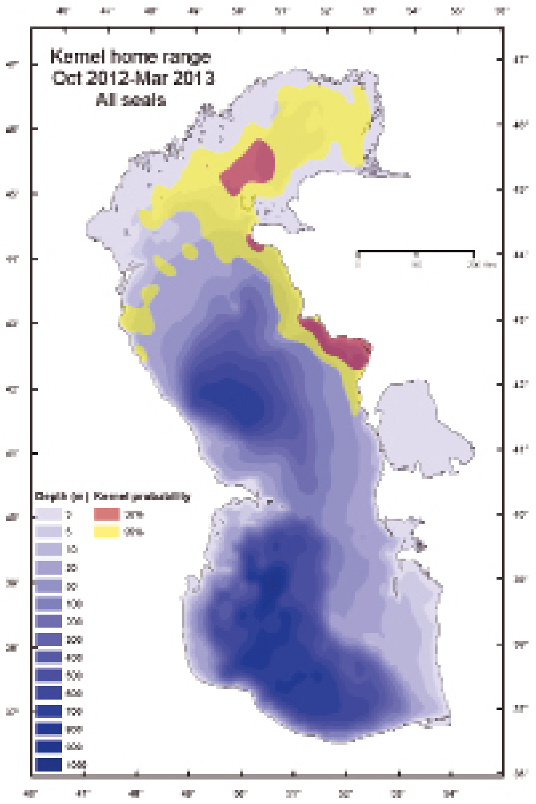


Figure 11.3.9 Habitat areas for the Caspian seals confined to a 95% density probability (shown in yellow) and a 50% density probability (shown in red) for the period between October 2012 and March 2013

fitted with WC-SPLASH tags of Wildlife Computer company (Washington, USA). Such tags provided the information not only regarding the location but also details of diving depth. The information on resurfacing and diving is an important supplement to the data about locations because it helps to understand what animals do in a specific location, i.e. feeding, resting, migrating, etc. and ensures more reliable interpretation of the nature of habitat use and a relative importance of various habitats in different areas.

Due to a limited return signal capacity, a SPLASH tag, as a rule, consolidates the data on seal resurfacing and diving every six hours (ratio of the number of resurfacing and diving in a specific depth range or the ratio of time spent at certain depths), and does not provide a full profile of the given data.

In 2010-2011 (autumn-winter), seals in the shallow North-East Caspian Sea dived mainly to depths of approximately 0-15 m, while the average maximum depth for each tag was 8-13 m. For those seals migrating periodically to deep-water areas to the south-west of Bautino, the shallow diving period alternated with episodic diving to depths of up to 100 m, and sometimes 220 m [CISS, 2010-2011].

In 2011-2012 (spring-summer), the average maximum diving depth for the entire 2011-2012 survey period was approximately 30 m, with fluctuations between 6.5 and 122 m (Figure 11.3.10). 60-98% of all resurface and diving cases

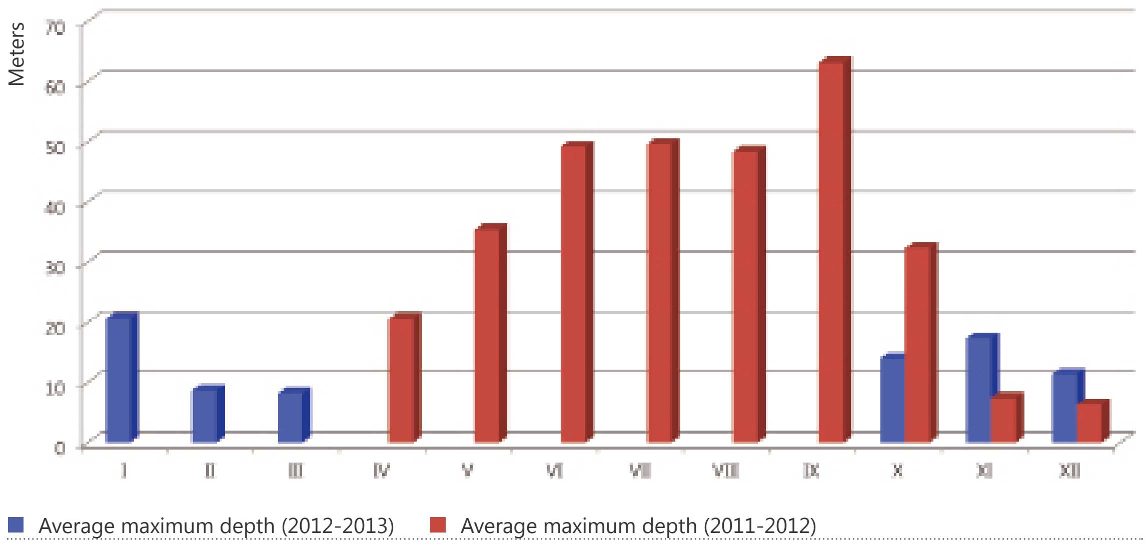


Figure 11.3.10 Change in the diving depth by months (two survey periods)

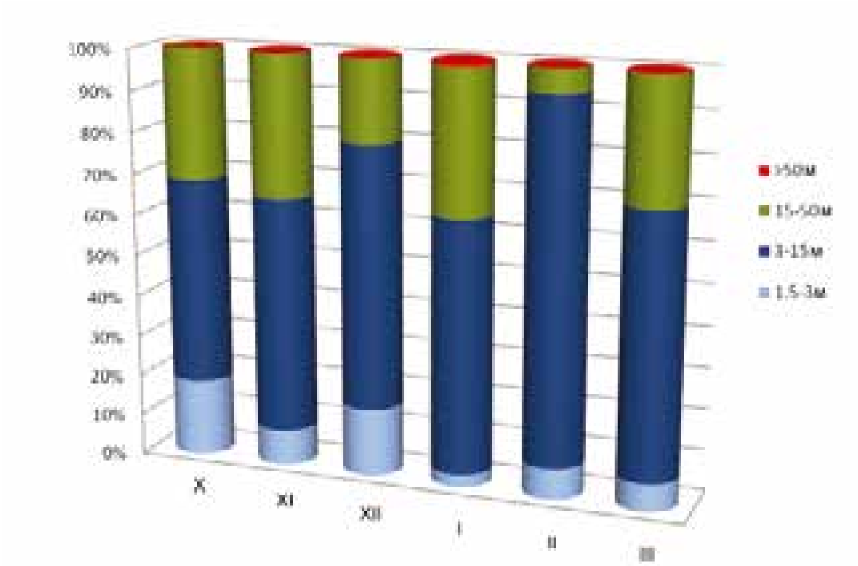


Figure 11.3.11 Percentage ratio of diving in various depth ranges for all seals during the survey period 2012-2013

were at a depth of more than 15 m [CISS, 2011-2012]. In November — December, the average maximum diving depth was lower than in previous months, it was closer to the data received from tagged seals in autumn 2010. Diving depth is probably related to availability of food, which can vary from season to season, and the sea area, and also on individual food preferences.

In 2012-2013 (autumn-winter), the average maximum diving depth registered for the entire tagging period was approximately 15 m with a diving range 1.5–128 m [CISS, 2012-2013]. It varied for each specimen in the average range 11–21 m. This is a lower value of the average maximum diving depth noted during 2011-2012 survey period (spring-summer). Such difference is related to winter distribution of seals (November 2012 — March 2013) which was confined to the shallow water of the North Caspian Sea. 65%–90% of all resurfacing and diving numbers were in the depth range 3-15 m (Figure 11.3.11).

The results of surveys in 2010-2013 identified that the majority of diving (over 60%) lasted less than 5 minutes. Less than 5% of diving for the entire survey period lasted for more than 10 minutes. Diving duration decreased in February-March when diving of less than 5 minutes accounted for 85-95% of all dives.

Conclusions

The surveys performed in 2008-2013 provided a reliable acknowledgment that the Caspian seal habitat covers the North Caspian Sea water area and the coastal waters of the Middle Caspian Sea.

When migrating to the north direction, the seals use a "migration corridor" from the border with Turkmenistan to the Zhaiyk River (Ural) estuary along the Kazakhstan coast, extending from the coast approximately to 50-m isobaths. The continuous use of this corridor over a number of consecutive years confirms its importance for seal migration. This fact needs to be taken into consideration when assessing the potential impact of commercial activities, including navigation and petroleum operations.

The survey data shows that some seals prefer fattening in certain habitats, for example, in shallow waters or in certain feeding areas confined to open waters or coastal areas.

The shallow waters of the North-East Caspian Sea from the Komsomolets bay to the Zhaiyk River delta are used by seals for migration, fattening and resting, and suh grounds are their autumn habitat. It is most likely that this area is also used by a major part the breeding adult population waiting for ice formation. Therefore, it is extremely important to take into account potential impact of any operations on the seals in this particular area in the autumn period.

Autumn-winter migration has a more complex nature than it was assumed before. The surveys acknowledged the behaviour of seals when they entered and left the ice covered area a number of times, and also migrated for feeding to the southern areas.

The majority of resurfacing and diving events was registered at 3-15 m depths. A major part of the seals did not dive to the depths below 50 m. Diving to 100 m depth or below was observed very rarely. The maximum diving depth was closely related to bathymetric conditions in the diving area. During the feeding period, diving duration did not exceed 5 minutes.

The Company's initiative to perform seal surveys with use of satilate tagging means involvement is a new technology to surveysuch endemic species in the Caspian Sea. Understanding of the identified aspects of seal life pattern is necessary in order to minimize a potential negative impact of the Company's operations and infrastructure on the seals population. Satellite remote measuring data together with the data received from other surveys allows to get the information required for planning the Company's operation in this respect.

Cumulative data on movements of the Caspian seal acquired with use of satellite remote measuring in various years can be used for a more careful analysis of habitats and migration routes alongside with other results of surveys (aerial surveys, vessel observations, etc.).

Further development of satellite remote measuring data through subsequent surveys would be very useful because it allows to identify the regularities in seals behaviour. Seals tagging in spring and summer could be considered as a primary direction of future surveys because the behavioural range in this period is significantly wider than in winter.

12. ORNITOFAUNA

The North Caspian Sea plays a global role in conservation of waterfowl and semiaquatic birds. This is demonstrated by establishment of several IBAs (Important Bird Areas - Key Bird Areas, an international list of globally important sites for conservation of the bird populations in the world) in its territory. In addition, the deltas of the Zhaiyk River (Ural) and the Volga River are declared as Ramsar lands that play a key role in conservation of wetland species. One of the most important routes in the Eastern hemisphere is the Siberian-Black Sea-Mediterranean flyway which is a part of the international AEWA Agreement (Agreement on Conservation of African-Eurasian Migratory Waterbirds - an international agreement on protection of the African-Eurasian flyway of Waterbirds). Moulting grounds and long migratory stops for fattening (feeding) are located here. In addition, coastal shallow biotopes and island systems are breeding grounds for a large number of water and semiaquatic birds.

Due to commencement of oil fields development in the Caspian Shelf, the world community began to pay close attention to the environmental status of the entire ornithological complex in the North Caspian Sea. Kashagan field and other Contract Areas of the Company are located quite closely to the places of birds' concentration and nesting, as well as to their flyways. Therefore, since 2000, regular annual observations of the bird numbers and registration of their concentration places are conducted here to minimize potential negative impact. At the initial stage, monitoring included autumn and spring aero-visual surveys.

Starting from 2008, the monitoring system has been expanded: surveys have covered all seasons; aero-visual surveys have been conducted during the migration period and in addition to a spring and one autumn surveys they included another autumn overflight (two autumn surveys 4-6 weeks long due to a lengthy autumn migration and birds' diversity). Moreover, in mid-June, additional aero-visual survey was conducted to identify the existing colonies and mass concentrations of birds that do not breed in this season. All results are recorded with references to coordinates. This Chapter provides results of aero- visual survey covering the coastal biotopes from Kazakhstan sector of the Volga delta to Tupkaragan Bay.

Also starting from 2008, in addition to aero-visual observations, summer and winter onshore surveys have been added: during the nesting period in the delta of the Zhaiyk River to determine the status and abundance of individual species and in winter, on the coastal area of Mangyshlak Peninsula (Mangystau), to determine the composition and abundance of the winter bird fauna. To study the intensity of the fly directly over Kashagan, short-term (3-5 days) observations of migrating birds from artificial islands are carried out in spring and autumn.

Since 2012, regular (seasonal) bird observations are conducted from onboard the vessels involved into offshore environmental surveys (scientific research vessels - SRV).

According to the reference data which was updated significantly with the results of monitoring carried out by the Company, more than 300 bird species are encountered in the North-East Caspian Sea. The species and quantity of birds depend on the season of the year, that is why the bird population structures reviewed by seasonal aspects differ significantly in each result.

12.1 Seasonal and long-term dynamics of the ornitofauna of the North-East Caspian Sea

This Section describes long-term monitoring results of ornitofauna [Reports on Birds, 2006-2016].

Monitoring Methodology

The methodology of surveys was changed at the workshop on the Company' monitoring (Atyrau city), which took place on March 11, 2009. Given the change in schedule for performance of surveys and the refined methodology (according to the Report "Review of the Program for Ornithological Monitoring during Kashagan Development - report on gap analysis and suggested recommendations" of international organizations ERM and BTO) the data acquired in 2006-2008 does not fit for mathematical processing and comparison with systematic data acquired with use of new methodology starting from 2009. This Chapter reviews the results of observations in 2009-2016 period.

The methodology used in the surveys conducted in 2009-2016 is based on standard methods of birds' in-life study. The onshore surveys involved a visual observation using binoculars (7x42) and a field telescope (Swarovsky) with 20-60 times amplification. The most interesting facts are recorded in the field logs with indication of the date, time, place of observation and coordinates confirmed by GPS. The log entries also include the data about birds seen (species type, gender and age, if possible, the number of species, conditions of observation, behavioral characteristics).

Aero-visual survey is conducted from a flying helicopter by two field observers - one on each side. Absolute count of birds (accurate or estimated) is carried out throughout the flight, records are taken at ten-minute intervals. At the start of each ten-minute interval, the coordinates are recorded. Knowing the average speed of the helicopter (about 150 km/h for the Eurocopter) and the width of the survey strip (500 m from each side with the total width of 1 km), it can be assumed that a 10-minute interval overflight covers the area of 25 km^2. If overflights are performed with an Agusta helicopter, the flight speed is almost always higher- 200-230 km/h, which increases the surveyed area in the 10-minute interval to 35 km^2. We call such area a "station".

Recording the coordinates at the start of a ten-minute interval helps to orientate within the surveyed site. Large concentrations of birds are recorded with digital cameras for further processing in the laboratory. All data is registered in a field log and then entered into the electronic database. The locations of the nesting colonies are recorded using GPS. Based on the acquired data, schematic maps for the location of mass concentrations and colonies of waterfowl and semiaquatic birds are developed. Any extrapolation with such records type is impossible.

The helicopter flies at a permissible height of about 100 m above the water surface and at the speed that allows the identification of most species. The flight route runs along the points established several years ago to ensure the data continuity.

DURING THE SURVEY, THE ROUTE IS ADJUSTED DEPENDING ON REAL LOCATIONS OF MASS CONCENTRATION OF BIRDS WITHIN VISIBILITY DISTANCE FROM THE HELICOPTER.

12.1.1 Specifics of Birds Distribution in Summer Period

Since 2009, monitoring surveys study a summer aspect of avifauna. They are held in the middle of June–the second half of June, at the time when the vast majority of species have fledglings in the nests, and helicopter flight over the colonies or concentrations of birds cannot cause damage to the eggs or nestlings in the nests. Moreover, birds keep staying within the colony areas, which allows to estimate their numbers and record the coordinates of the area colonized in this season.

In the second half of June, the nesting species are mainly found in the North Caspian Sea, although not all birds recorded during the survey are involved in reproduction process in this area. An example is the *Cygnus olor* swans, which although nest in the North Caspian Sea in large numbers, are also represented here in summer by major molted concentrations of immature specimens (this species starts to reproduce at the age of four years) and adult specimens that do not participate in the reproduction process at this time for some reasons.

Some species (mallard, Red-Crested Pochard) that are breeding in the North Caspian Sea already in June form large molted flocks (often they are ducks that are not involved in escorting their ducklings, and females who lost their eggs or nestlings). The white-tailed eagle (*Haliaeetus albicilla*) is mainly represented by young stray specimens, although some individual pairs are nesting in the area under survey - both in the Volga delta and in the delta of the Zhaiyk (Ural) River. However, the main part of the recorded birds during the survey are the nesting species.

During each aero-visual survey, representatives of more than 30 species have been recorded. In order to understand the situation better they are grouped according to classification[1]. The group "Pelicans" includes 2 species - White (*Pelecanus onocrotalus*) and Dalmatian (*Pelecanus crispus*) pelicans represented mostly in equal proportions. It should be noted that the Dalmatian pelican annually colonizes the reed beds area of the North Caspian Sea, especially in the deltas of the Volga and Zhaiyk Rivers, while the White pelican is mainly found in feeding concentrations. Only twice the nesting colonies were recorded, which proves its irregular nesting in this area.

"Cormorant" group is represented by two species. Pygmy cormorants (*Phalacrocorax pygmaeus*) form dense nesting colonies (together with various herons, Night Heron and Glossy Ibis) in delta areas, with the total number of 2,000-4,000 pairs, and are found near the colonies. The Great Cormorant (*Phalacrocorax carbo*) is a successful species, forming colonies both on the northern coastline (often as an addition to the pelican colonies) and in the region of the Seals Islands, where major mono-species settlements of up to 2,000-3,000 pairs of this species are located.

"Flamingo" group is represented only by one species (*Phoenicopterus roseus*), which stays in shallow waters through the summer period in Komsomolets Bay area, at the coastline of the Bozashchy Peninsula and in the Seals Islands area. Almost every year a large Flamingo colony is observed far away in Komsomolets Bay. This is confirmed by the first autumn records, when large flocks of gray young birds still learning to fly are observed, and they are accompanied by small groups of adult "teachers". However, we have never managed to find a living colony

Nestlings of the Dalmatian Pelican (*Pelecanus crispus*)

The Great Egret (Egretta alba) colony (*Egretta alba*)

located far away in non-accessible sors and also away from our routes.

"Ciconiiformes" group is represented by Great Egret (*Egretta alba*) and Little Egret (*Egretta garzetta*) nesting in the described area, Grey Heron (*Ardea cinerea*) and Purple Heron (*Ardea purpurea*), as well as the Spoonbill (*Platalea leucorodia*) and Night Heron (*Nycticorax nycticorax*), which are counted during the overflight, however, not in full extent. Quite numerous Glossy Ibis (*Plegadis falcinellus*) are almost never recorded during the survey due to their small sizes and covert behavior. The basis of this group is formed by Grey Heron whose nesting population in the survey area, according to our estimates, reaches about 3,000 pairs.

Swans in the summer period are represented only by Mute Swan *(Cygnus olor)* with occasional single species of Whooper Swan *(Cygnus cygnus)*. Moreover, a significant part of Mute Swan recorded in summer includes immature birds younger than 4 years, which stay mostly in the area of the Seals Islands by finding ideal conditions in the shallow water for feeding and minimal disturbance from people.

River Ducks include mainly Mallards (*Anas platyrhynchos*) nesting in the North Caspian Sea with a small number of other species, which do not participate in breeding this particular year for some reason and have not left convenient habitats.

The sea ducks are represented by 80-90% of the Red-Crested Pochard (*Netta rufina*), with some Pochards (*Aythya ferina*), which occasionally nest here, as well as small numbers of Tufted Ducks (*Aythya fuligula*) that are not breeding in this season.

Coot (*Fulica atra*) stays in nesting areas during the summer surveys and hides in reeds at the slightest danger, therefore, it is not seen, and aerial survey data does not give an idea of the coot nesting number in the coastal biotopes reaching thousands of pairs. This group is included in the tables for a visual comparison of its numbers in different seasons.

Seagulls and terns are represented mainly by mass species of gulls – the Great Black-Headed Gull (*Larus ichthyaetus*), the Herring Gull (*Larus cachinnans*), the Common Black-Headed Gull (*Larus ridibundus*), the Slender-billed Gull (*Larus genei*), the Common Tern (*Sterna hirundo*), the Sandwich Tern (*Thalasseus sandvicensis*) and the Caspian Tern (*Hydroprogne caspia*). All these species nest mainly on islands, often using artificial structures, which provides a suitable nesting environment. According to the data in Table 1, it can be noted that this factor resulted in a gradual increase in abundance of this group till 2012, and thereafter, such growth had stopped, however, remained at a stable high level.

Sandpiper is a combined group consisting of a number of species, playing an important role in migration seasons, and in summer the birds that do not nest in the current season are included in that group, they are flying birds that spend summer in shallow waters.

The results of surveys are shown in Table 12.1-1.

The data in the Table indicates that the number of birds varies throughout the years, however, a number of factors, both objective and subjective, should be taken into account. The objective factors include climatic conditions of the season that have impact on the successful breeding of birds, and on their numbers as a whole, as well as surge events in the survey period. The subjective factors include the timescale of surveys relative to the timescale of mass nesting which vary from season to season, the duration of an efficient helicopter flight which depends on many technical reasons, weather conditions, etc.

The results of two surveys in 2014 and 2016 can be used for comparison. Both surveys were conducted on later than usual calendar dates, however, the results are almost double different (Table 12.1-1). This can be explained by a number of reasons. First of all, in June 2014 the efficient flight time was 50 minutes longer, i.e. 5 additional stations (more than 150 km^2) were surveyed in comparison to 2016. This allows exploring the Komsomolets Bay not only in the area of its mouth but also much further to the east and that immediately impacted the results - a record number of flamingos who stayed in a further part of the Gulf, closer to the nesting areas, and also increased number of swans who also stayed in that area was registered. Because of later dates of the overflight some Great Egret nestlings had already left the nests, started flying and were counted together with adult birds (normally we do not count the nestlings in nests). In 2016, due to the ongoing drop in the Caspian Sea level and down-surges, Komsomolets Bay became almost dry, and had significant mud areas, unsuitable for flamingos and swans.

Figure 12.1.1 shows the bird distribution in summer 2016 and the accepted split of the coastline into major areas:

- The Volga-Ural interfluve (between the Volga and Zhaiyk Rivers)
- Ural-Emba interfluve (between the Zhaiyk and Zhem Rivers)
- The mouth of Komsomolets Bay and the coast of the Bozashchy Peninsula
- Seals Islands

Table 12.1-1 Results of aero- visual surveys during the breeding seasons in 2009-2016.

Year	2009	2010	2011	2012	2013	2014	2015	2016
Date	13-14 June	13-14 June	11-12 June	20-21 June	12-13 June	18-19 June	13-14 June	18-19 June
The total recorded number	**100.4**	**122.6**	**144.3**	**134.5**	**116.7**	**203.2**	**137.8**	**109.6**
Number of stations	**38**	**41**	**44**	**39**	**34**	**45**	**42**	**40**
Density (thousands of specimens per station)	**2.6**	**3.0**	**3.3**	**3.4**	**3.4**	**4.5**	**3.3**	**2.7**
Including								
Pelicans	3.9	4.3	0.5	2.4	2.9	5.5	4.5	3.1
Cornorant	19.0	19.5	12.3	30.1	10.8	20.5	11.3	13.3
Flamingo	27.5	27.2	33.1	1.2	17.1	60.3	28.8	7.9
Ciconiiformes	3.5	4.8	5.9	7.5	5.9	8.3	7.1	3.8
Swans	13.9	25.7	28.1	18.1	16.0	39.2	34.7	32.3
River ducks	2.7	4.5	5.1	2.8	4.7	4.9	6.2	5.6
Sea ducks	2.1	6.6	4.8	4.1	12.5	19.5	8.1	8.3
Coot	0.1	0.1	1.0	1.2	0.2	3.4	0.8	0.1
Seagulls and terns	26.0	29.3	52.1	67.1	45.4	40.1	34.9	32.8
Sandpiper	-	0.2	0.9	0.1	1.8	1.3	1.0	2.3

Note: *the number of birds is given in thousands of specimens*

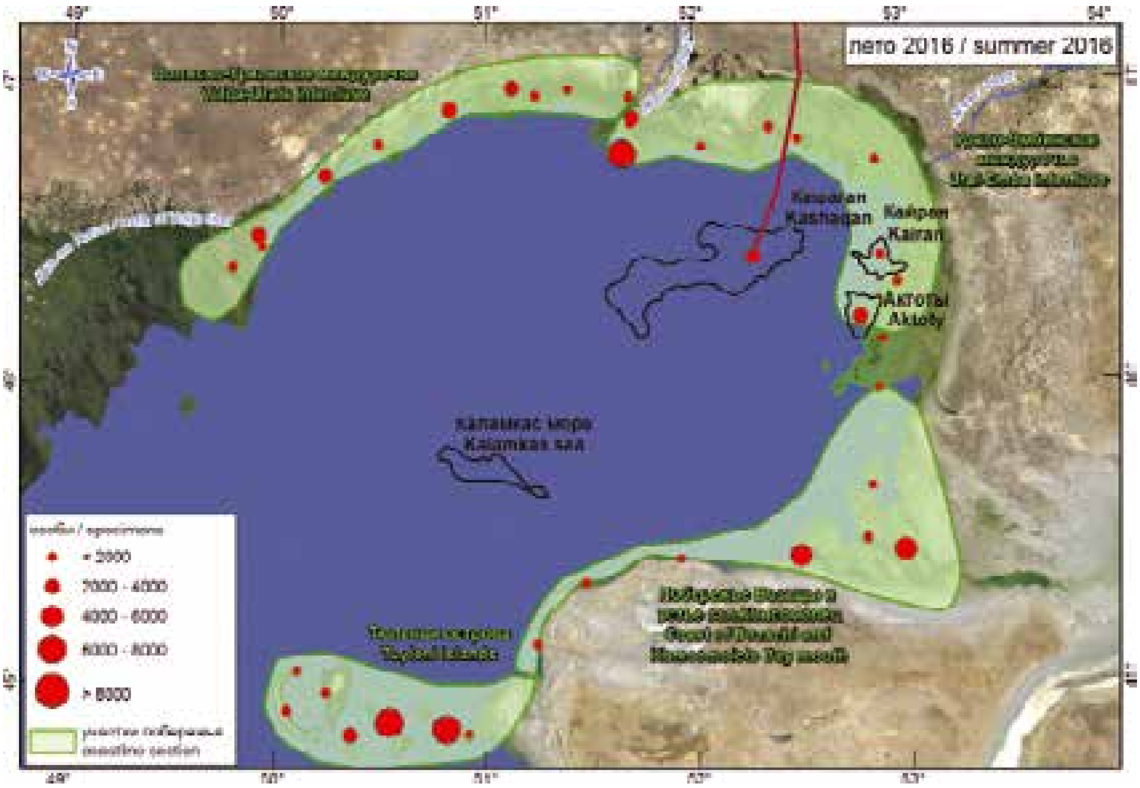
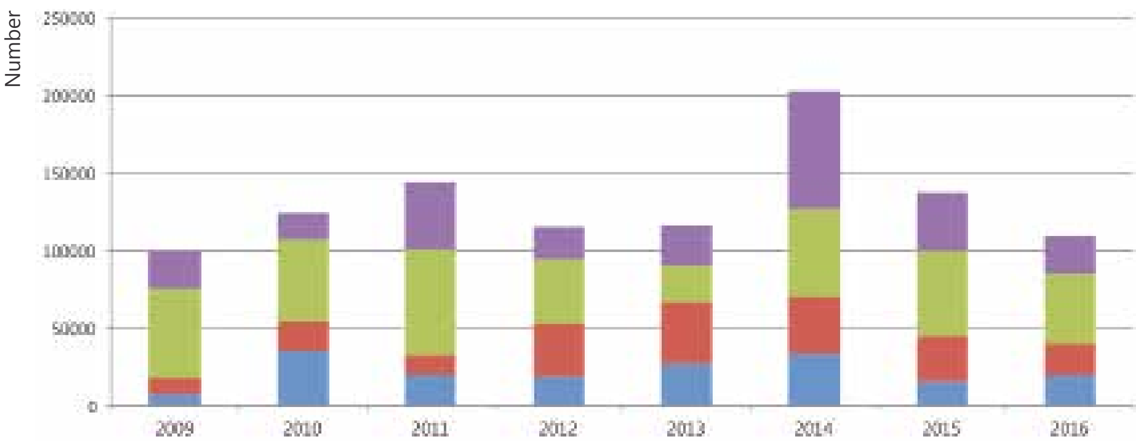


Figure 12.1.1 The distribution of the bird population in summer 2016

Figure 12.1.2 shows a graphical distribution of the total bird numbers counted in summer by years, broken down into major coastal areas.

It is evident from the graph that in different years this or that area plays a greater or a smaller role in distribution of birds in the North-East Caspian Sea. In order to illustrate the mobility of the avifauna within the survey area, it is possible to compare the distribution of bird numbers in different years



Komsomolets bay | Tuyleni islands | The Ural-Emba interfluve | The Volga-Urals interfluve

Figure 12.1.2 The distribution of the bird population in summer by years and by geographical areas

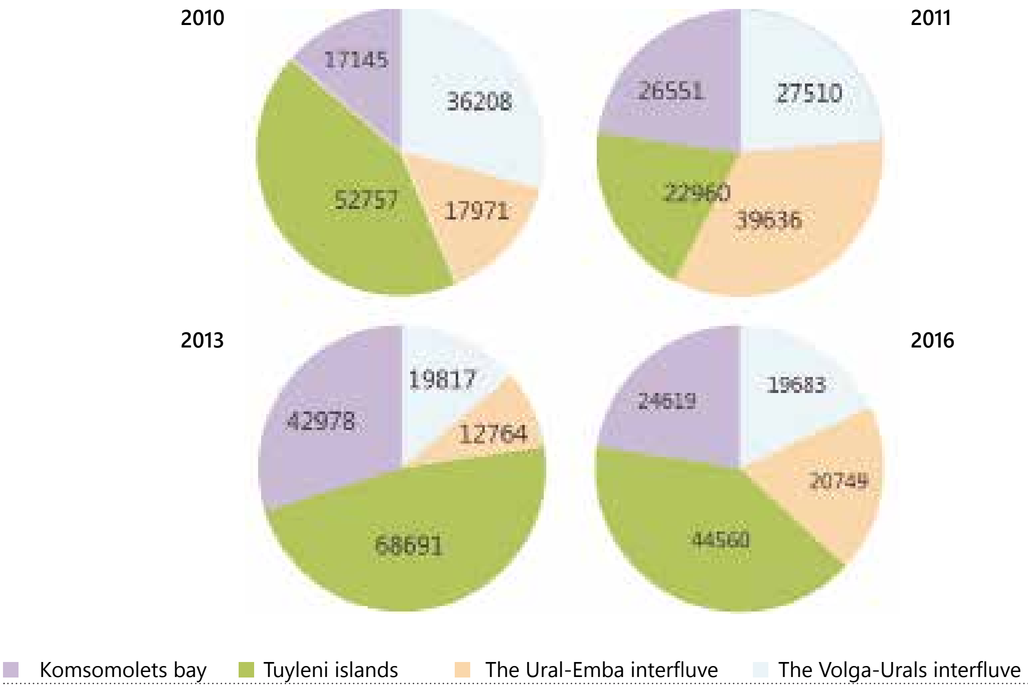


Figure 12.1.3 Differences in distribution of bird numbers by geographic areas. Summer 2010, 2011 and 2013.

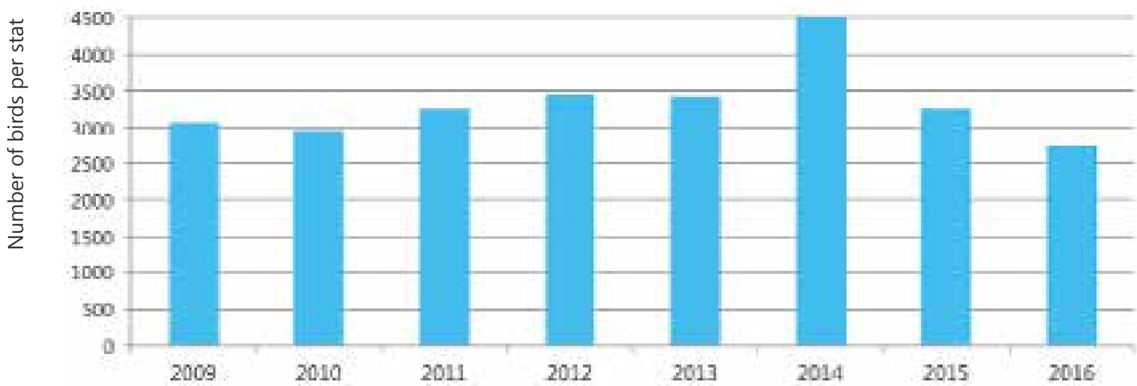


Figure 12.1.4 Differences in bird population density, on average, for all records per years (summer)

by major areas (see Figure 12.1.3).

These graphs clearly demonsrate that despite quite similar values of taken records (from 116.7 to 144.3 thousand), the distribution of birds by major areas differs significanly: in 2010 and 2011, the main proportion of birds (42 and 47% of the total number) stayed on the Seals Islands, and in 2013 the highest number of birds was found in the Ural-Emba interfluve (33.5%), while the Seals Islands accounted only for 23%.

If we level out the subjective and objective factors that have impact on survey results (for example, efficient time flight and weather conditions during surveys, surges, etc.), and build a graph based on the average value for all records of birds' density per station, then the fluctuations over the years become less (Figure 12.1.4).

In general, despite the changes in numbers, it can be stated that the summer bird fauna in the North-East Caspian Sea is quite stable and does not demonstrate any trends to decline. It should be also noted that the whole area of the North Caspian Sea from the Volga delta to the Seals Islands and Mangyshlak Bay is a single ecosystem that responds to changes in conditions in some part of the redistribution of bird masses in the same region.

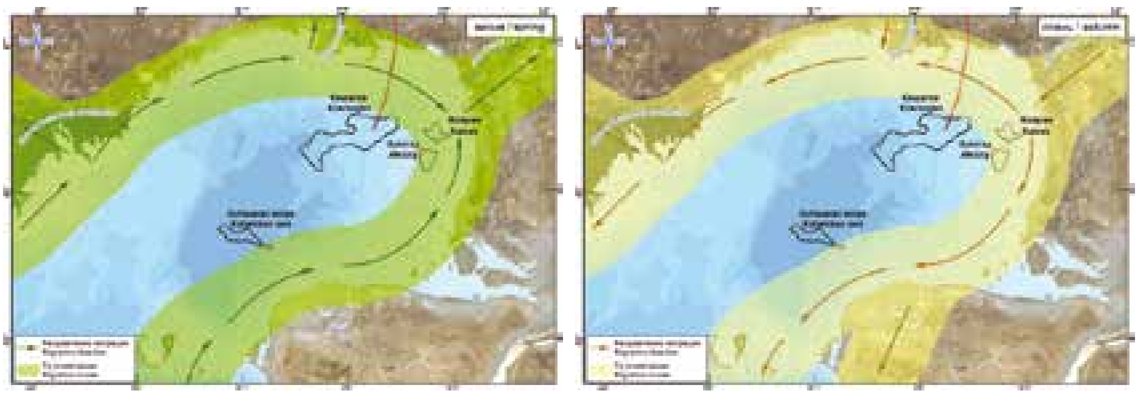
12.1.2 Ornithofauna in the seasonal migration periods

The bird fauna represented in the North-East Caspian Sea during migration period, is a complex aggregate of species with birds breeding in the area and directly depending on its environmental well-being, as well as large concentrations of migrating birds that fly in spring to nesting sites in Siberia and a tundra zone, and in autumn to wintering sites in the Mediterranean and Africa (Figure 12.1.5). Due to the complex composition and mobility of the avifauna during seasonal migrations, the survey results cannot characterize the environmental well-being of the region, as it does for the breeding season. In spring, the number of birds can reflect the wintering, and in autumn - well-being of the nesting season. However, the environmental situation in the North-East Caspian Sea is a key condition for stability of the avifauna in a vast region, not only in the Pre-Caspian region, but also in the Western Siberia.

Spring migration takes usually short time, 1.5-2 months and often starts with the beginning of the breeding season for local birds. The autumn migration is extended to 2.5-3 months (from mid-August to mid-late November), birds that have finished their nesting stay for a long time in favorable areas of the northern shallow part of the Caspian Sea for moulting, resting and gaining energy for further flying to wintering areas. That was exactly the reason why 2 aero-visual surveys have been conducted since autumn 2009, with 4-6 week intervals, because during this period, the composition and number of birds' concentration changes significantly.

As stated above, it is not correct to compare the 2006-2008 survey results with the survey period of 2009-2016. Therefore, only brief summary of the observation results for 2006-2008 is provided here. In the given period the following aero-visual surveys were carried out: in spring 2006 (April), an overflight between Zhambai and the Zhem (Emba) rivers was conducted, 27 stations were involved (the sizes of the stations do not correspond to those used in future); in total, 97,000 birds and 30 species were recorded. In autumn 2006 (November), the survey covered the area between the Delta of the Zhaiyk River and the mouth of the Zhem (Emba) River. In total, 18 birds' concentration areas were noted with 58,400 birds and 27 species recorded.

In spring 2007 (April 7-8), aero-visual surveys were carried out in full scale - 49 stations were involved with 104,000 birds of 36 species recorded. In autumn 2007 (October), a one-day survey was conducted on the northern coast of the Caspian Sea, during which 37 stations were visited and the total number of 80,000 birds was counted. In spring 2008, 29 stations were visited on the northern coast, 44,800 birds were counted. In autumn 2008, the monitoring started



a – Spring season

b – Autumn season

Figure 12.1.5 Main directions of bird migration in accordance with the schedule. This aero-visual survey served as an example and became the basis for development of a new methodology used for studies up to date. Since this period, the data is subject to further mathematical processing and can be compared with each other. On October 25-26, 2008, 48 stations were involved with the total number of 165,000 birds of 34 species counted.

Spring

During spring aero-visual surveys about 40 bird species were recorded: a great-crested grebe of the Grebes (*Podicepideformes*); Pelecaniformes - Dalmatian Pelican and White Pelican, Pygmy Cormorant and Great Cormorant; Ciconiiformes - spoonbill, Little Egret and Great Egret, Grey Heron and Purple Heron; Phoenicopteri - Flamingo; Anseriformes - no less than 16 species (mute swan and whooper swan, Shelduck, Mallard, Shoveler, Pintail, Gadwall, Teal and GarganeyTeal, Red-Crested Pochard, Tufted Duck, Pochard and Scaup, Smew, Goldeneye, White-Headed Duck, Long-Tailed Duck, some of them were counted in concentrations without detailing to species); Birds of prey (*Falconiformes*) – duck-hawk and sometimes dove-hawk, White-Tailed Eagle; Gruiformes - coot; Charadriiformes - at least 10 species (Pied Avocet, Great Black-Headed Gull, Common Black-Headed Gull, Slender-billed Gull, Herring Gull, Common Gull, Common Tern and Sandwich Tern, Caspian Tern, various sandpipers).

In the period 2009-2016, 7 two-day spring aero-visual surveys were conducted and in 2011 - 1 one-day aero-visual survey was performed. It should be noted that the results of aero-visual surveys directly depend on dates of their performance, and, even to a greater extent, on the combination of the surveys dates and spring conditions (late, early, lengthy winter, etc.). The results are shown in Table 12.1-2 and Figure 12.1.6-12.1.8.

As seen from the above graph, the total number of birds increases slightly over a number of years. In addition to objective reasons, this can be explained by the change in the type of helicopter used, which had an impact on survey results (the first generation helicopters Bell, Sikorsky, Eurocopter had a slower speed and, therefore, covered a smaller area, while the latest generation helicopter Augusta, (introduced into operations in 2015), made it possible to survey bigger areas and had increased the surveyed area of one station by about 20 %, which can be seen from the higher results of the last two years.

Table 12.1-2 Results of aero visual surveys during spring migration periods in 2009-2016.

Year	2009	2010	2011	2012	2013	2014	2015	2016
Date	18-19 April	10-11 April	9 April	6-7 April	6-7 April	12-13 April	11-12 April	9-10 April
Spring conditions	Early spring	Late spring	Late spring	Late spring	Early spring	Late spring	Late spring	Late spring
Всего учтено	77.1	155.3	110.0	177.7	120.6	154.7	261.1	195.7
Number of stations	45	40	24	44	42	41	47	43
Density (thousands of specimens per station)	1.7	3.9	4.6	4.0	2.9	3.8	5.6	4.6
Including								
Pelicans	0.8	1.1	0.5	1.0	0.4	0.7	1.1	1.1
Cornorant	9.5	5.4	1.4	7.6	4.5	10.7	16.9	7.9
Flamingo	10.2	3.7	-	35.6	13.3	17.2	47.3	46.2
Ciconiiformes	2.7	4.2	0.3	1.9	2.3	3.3	3.3	1.9
Swans	3.6	6.9	9.6	7.8	3.7	7.5	7.6	7.4
River ducks	14.7	44.8	43.7	65.6	32.1	39.7	53.6	39.8
Sea ducks	4.7	22.7	17.3	17.2	11.7	7.2	27.2	8.7
Coot	13.0	12.2	4.9	18.0	3.5	5.1	49.3	16.0
Seagulls and terns	13.1	51.5	23.8	17.4	37.5	56.3	50.4	64.4
Sandpiper	3.8	4.2	5.7	3.3	8.1	5.2	5.7	2.2

Note: the number of birds is given in thousands of specimens

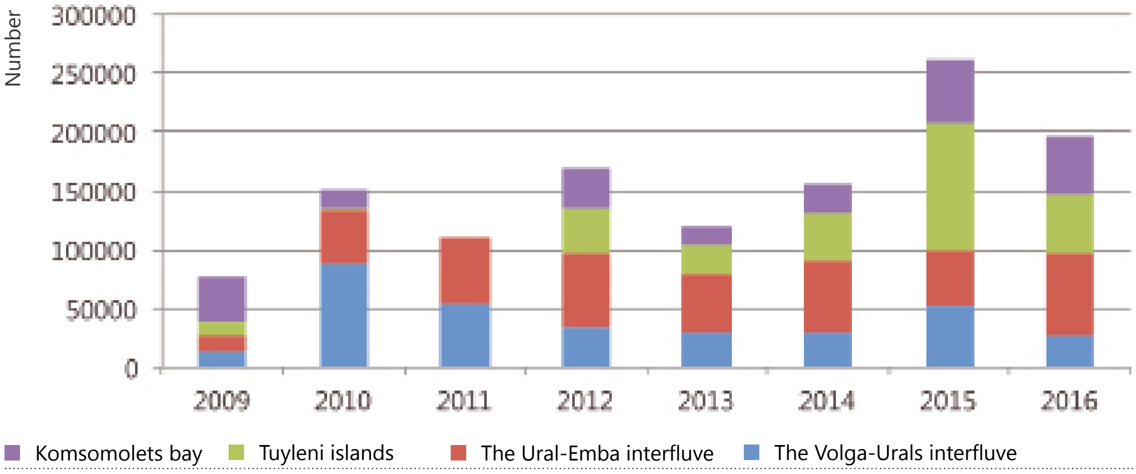


Figure 12.1.6 Total number of birds recorded during spring aero-visual surveys

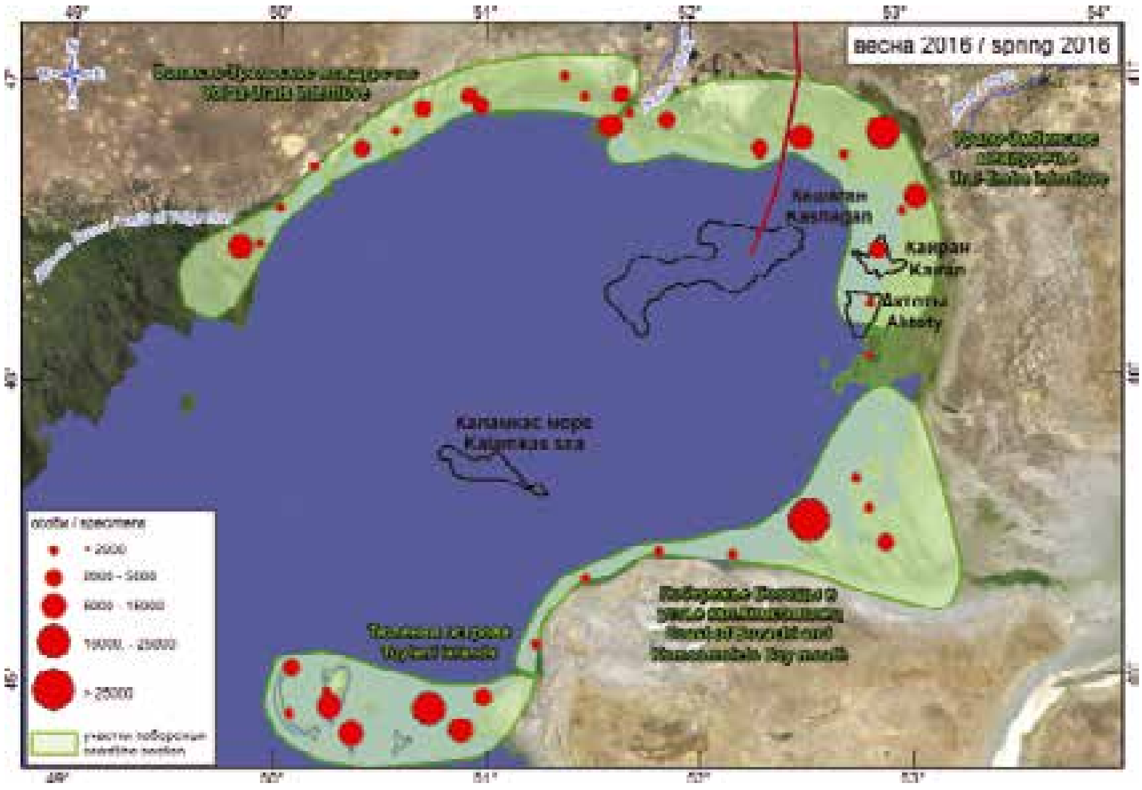


Figure 12.1.7 Distribution of the bird population in spring 2016

Figure 12.1.6 shows that over the years the proportion of birds recorded along the northern coast between the deltas of the Volga and Zhem (Emba) rivers is decreasing, and the proportion of birds recorded within the Seals Islands area and in the mouth of Komsomolets Bay is increasing. This is explained by a continuous drop in the Caspian Sea level and the drying up of a large habitat area convenient for aquatic bird species.

Figure 12.1.8 Bird density during the aero-visual surveys conducted in spring

However, given the differences in the surveys conducted, in particular, the different number of stations involved, the most informative is comparison of the average bird density, i.e. specimens per station -about 30 km^2 (Figure 2.1.8).

As it is seen from the graphs, the number of birds during the spring migration in the North Caspian Sea is quite stable with a slight trend to increase.

During the spring aero-visual surveys, the first half of April coincides usually with the end of migration for the northern duck species (Goldeneye, Pintail, Wigeon, Tufted Duck, etc.), the beginning of the formation of colonies for Great Egret, both Pelican species, Great Cormorant, Great Black-Headed Gull, Herring Gull and Caspian Tern, as well as the peak time for arrival of the Grey Heron and the Little Egret. A number of species (Pygmy Cormorant, Purple Heron, Spoonbill) arrive later. Some species are already in the area of new colonies.

Autumn

Due to lengthy autumn migration of birds, autumn monitoring surveys are conducted in 2 stages - at the end of September and at the end of October, although in different years the dates changed depending on circumstances. The results of autumn overflights are always significantly higher than spring and summer outcomes, since after the nesting season not only adults but also young birds are counted. Often, the autumn surveys data is used to update the summer results. Autumn is the season when it becomes evident how successful was the nesting season for Flamingos, or the White Pelican.

During the autumn aero-visual bird observations about 40 species were recorded: almost identical to the species recorded for the spring migrations, but in other proportions. Moreover, the proportion varies between two autumn records - some species (Herons, Flamingos) had a high abundance at the first stage, at the end of September or in early October, and had almost completely gone by the time of the second survey. At the same time, the number of Sea ducks and Anas that nest to the north, and coots are increasing rapidly. Such species as Goldeneye and Mergus (Goosander and Mergus serrator) appear only by the second survey of the autumn period.

The autumn survey results are shown in Table 12.1-3.

Figures 12.1.9-12.1.11 show not only a gradual increase in the number of birds over the years, but also an increase in the role of the Seals Islands (green colour), as well as a relative decrease in the role of other geographical areas - the northern coast of the mouth of the Komsomolets Bay throughout the years.

The major part of abundance in the autumn concentration of birds is represented by several species - flamingo, mute swan, red-crested pochard, and bald-coot. For example, in 2015, during the first stage of the autumn survey, these

Table 12.1-3 Results of aero-visual surveys conducted during the autumn migration period in 2009-2016.

	2009	2010	2011	2012	2013	2014	2015	2016
Stage 1	**26-27 september**	**25-26 september**	**27 and 29 september**	**2-3 october**	**24 and 26 september**	**20-21 september**	**19-20 september**	**15-16 september**
The total number of specimens	**337.2**	**302.8**	**328.8**	**371.0**	**351.7**	**405.2**	**416.1**	**498.5**
Number of stations	**43**	**38**	**50**	**40**	**36**	**42**	**35**	**41**
Density (thousands of specimens per station)	**7.8**	**8.0**	**6.6**	**9.3**	**9.8**	**9.6**	**11.9**	**12.2**
Including								
Pelicans	2.1	0.9	4.3	1.4	3.9	3.1	3.3	5.4
Cornorant	5.6	7.6	20.6	7.5	12.7	23.6	11.1	33.2
Flamingo	13.1	28.9	52.1	49.1	22.2	27.0	47.0	1.9
Ciconiiformes	6.4	9.4	12.6	6.4	15.3	14.5	7.9	11.3
Swans	23.8	33.6	25.3	23.3	31.5	37.9	40.5	61.5
River ducks	126.8	126.5	117.8	106.3	99.2	59.6	84.1	54.3
Sea ducks	42.2	27.3	6.4	19.7	26.2	32.7	59.1	52.4
Coot	47.8	13.2	30.0	101.7	19.7	143.9	83.1	133.3
Seagulls and terns	48.6	38.4	41.7	34.5	97.4	51.4	74.7	89.7
Sandpiper	13.0	12.8	13.7	15.7	17.9	7.6	3.6	15.1
Stage 2	**7-8 november**	**6-7 november**	**8 november**	**October and 1st of November**	**22-23 october**	**11-12 october**	**24-25 october**	**22-23 october**
The total number of specimens	**332.3**	**262.9**	**77.0**	**294.3**	**411.6**	**337.9**	**344.8**	**513.8**
Number of stations	**51**	**34**	**25**	**40**	**38**	**53**	**35**	**40**
Density (thousands of specimens per station)	**6.5**	**7.7**	**3.1**	**7.4**	**10.8**	**6.4**	**9.8**	**12.8**
Including								
Pelicans	1.7	3.8	1.1	4.2	1.9	4.4	1.8	2.5
Cornorant	5.8	7.2	3.8	4.4	4.8	4.4	13.5	31.1
Flamingo	0.2	0.1	-	14.6	19.4	38.6	4.4	14.5
Ciconiiformes	0.9	0.4	0.1	1.2	0.4	2.4	0.9	1.8
Swans	35.2	21.1	9.1	23.4	33.7	36.2	45.4	72.6
River ducks	139.2	119.8	19.7	188.0	109.4	70.2	43.9	69.1
Sea ducks	19.6	6.9	26.8	30.3	6.5	66.5	76.4	105.9
Coot	55.6	40.5	0.2	64.9	108.4	61.2	115.6	160.2
Seagulls and terns	45.2	57.8	14.1	38.8	68.5	40.8	32.0	35.6
Sandpiper	2.8	1.0	0.1	6.8	9.3	9.6	8.3	9.4

Note: *the number of birds is given in thousands of specimens*

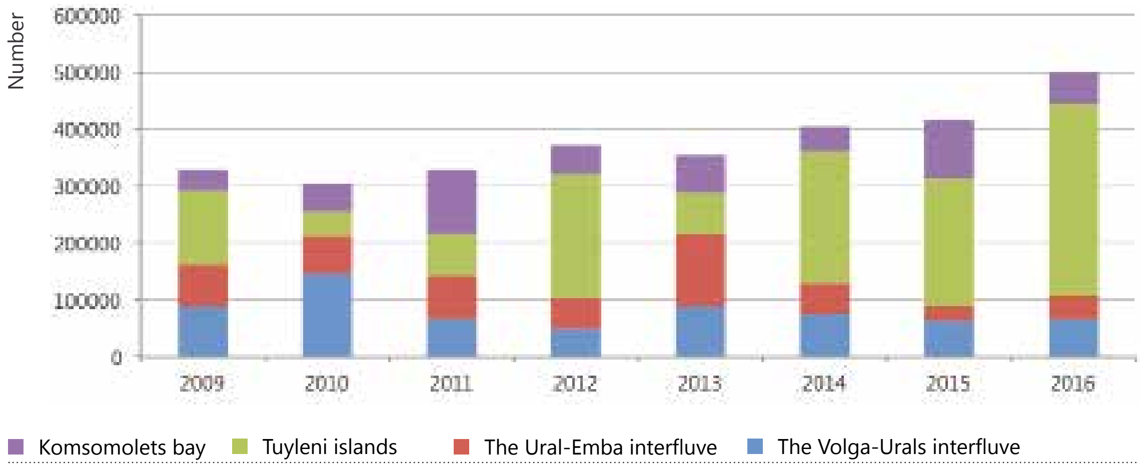


Figure 12.1.9 The total number of birds recorded at Stage 1 of aero-visual surveys conducted in autumn

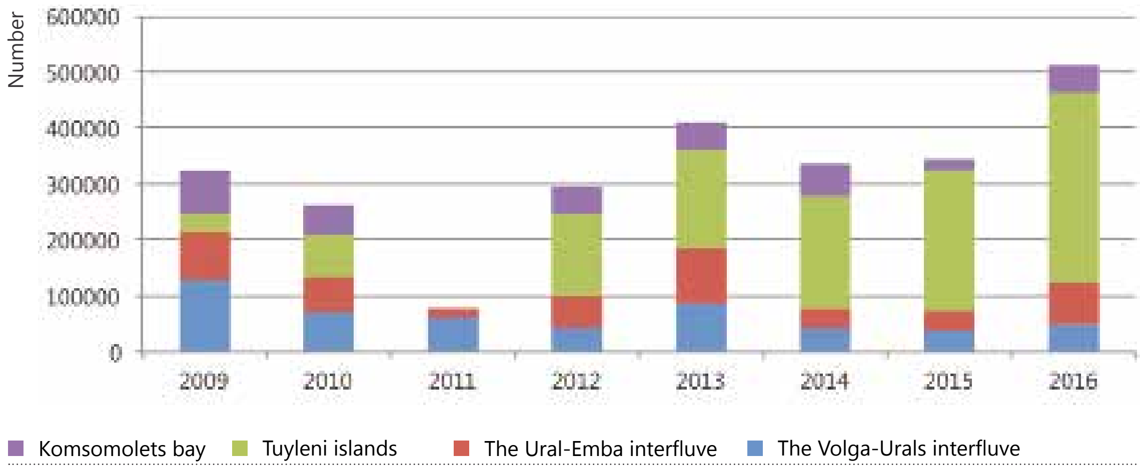


Figure 12.1.10 The total number of counted birds at Stage 2 of autumn aero-visual survey

four species collectively accounted for 60 % of all birds counted during a two-day overflight, and 69 % at the second phase. The remaining 30-40 % fall on representatives of other 35-38 species of birds.

12.1.3 Observations of Birds at Artificial Offshore Structures

In addition to surveys of birds' fauna in different seasons of the year at coastal biotopes from the eastern part of the Volga delta to Bautino, since 2008, observations have been conducted at offshore artificial structures of Kashagan, Kairan and Aktote fields. For this purpose, the field was visited shortly during spring and autumn migrations, as well as during a nesting period.

Artificial islands are land sites built in the open water of the North-East Caspian Sea, which are gradually inhabited by birds not only during their migration but also for nesting. Migratory birds that have crossed this area in transit before, now stop here. Some species use artificial islands for a short rest or they wait for the right time of day (night migrants – await darkness), other species stay here for a longer period to restore their energy resources required for continuation of migration.

Artificial islands are mostly visited by night migrants that cross the sea and are attracted by night lighting. The birds stopping here are often exhausted, they need rest and replenishment of energy to continue the flight. If, within a short

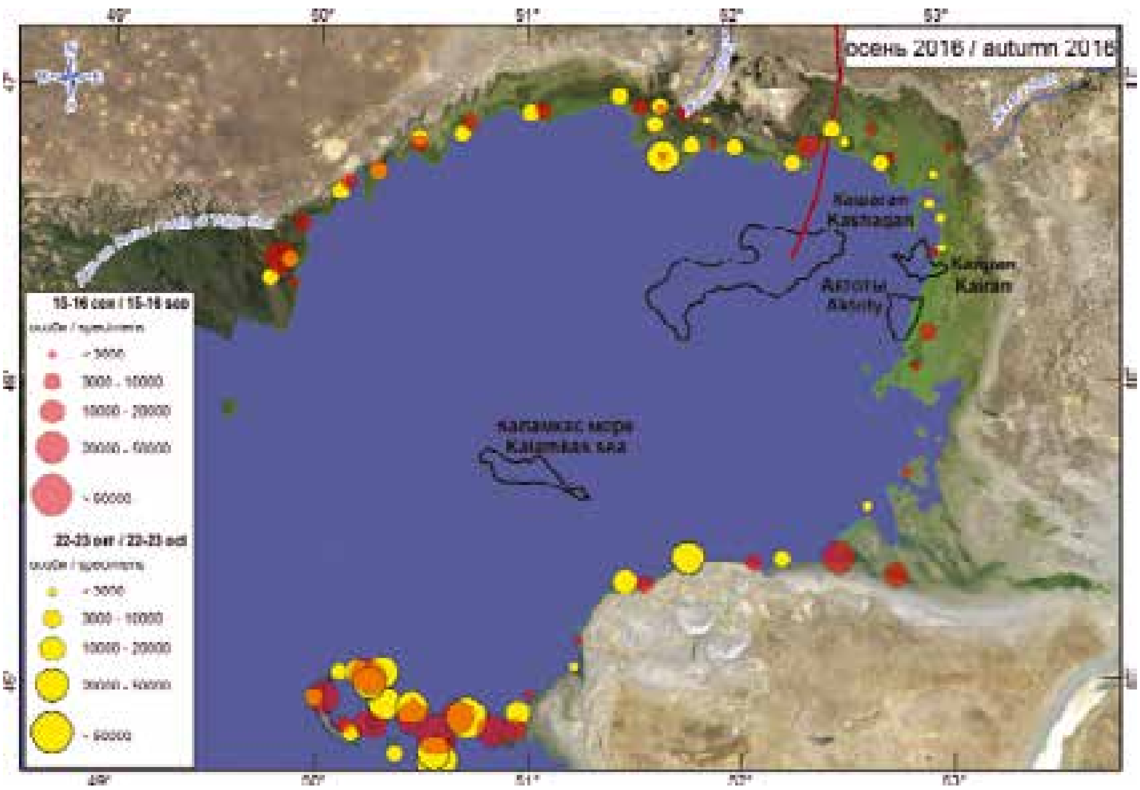


Figure 12.1.11 Distribution of autumn bird population in 2016

period of time, they do not find the food (and often this is hampered by cold windy weather that prevents insects from leaving their shelters in various cracks), insectivorous birds continue to weaken till complete exhaustion and death. This is most often explained by finding dead passerines on the islands. Due to availability of an easy target in the form of weakened birds, some predators always stay on the islands (kestrels, sparrows, small gray bird sprouting small sparrow birds). Weakened or dead birds are a feed stock also for crows (gray crow, rook), who can easily leave an island because of their flying qualities, but they prefer to stay till the number of weakened migrants here disappears.

Our observations indicate that the islands are used by birds of the most diverse environmental groups (forest, water, open-space birds). In spring, 145 species of birds are noted here, in autumn - 136, the total list of birds observed during seasonal migrations consists of 187 species (Annex 8, Table A1). At the structures and in their close proximity, 12 species listed in the Red Book of Kazakhstan - Dalmatian pelican, spoonbill, glossy ibis, whooper swan, osprey, steppe eagle, white-tailed eagle, Saker Falcon, peregrine falcon, little bustard, great black-headed gull, black-bellied sandgrouse, were recorded.

Company's activities in Kashagan area resulted in emergence of new habitats for seabirds. Previously, variegated and river terns, who establish joint colonies across the world, nested in the North Caspian Sea on low sandy spits that appear in shallow waters near the shore.

Such location of nesting colonies often leads to their sweeping away by a storm, flooding during surging, death of colonies from land predators (wolves, foxes), overcoming shallow areas by foot or by swimming. This makes these bird species vulnerable (especially it refers to the sandwich tern, who is tied to the sea coasts, while the river tern is more flexible in selection of nesting grounds, and lives in any inland waters of Kazakhstan).

A number of artificial islands and ice protection barriers were built for Kashagan development. They are suitable for nesting of semiaquatic birds. A special role is played by ice protection barriers, which are rarely visited by people. These barriers

Colony of Sandwich Tern *(Thalasseus sandvicensis)* on DC05 Island (Kashagan)

are rather high above the water, therefore, the colonies are not washed away by storms, and their location is far away from the shore that does not allow ground predators to arrive here. At the same time, the unpolluted marine environment around the islands allows for large quantities of fish to accumulate here (and nightlight even attracts it), which makes the feed stock for these birds stable and rich. It provides for a better reproduction of these species of birds than in natural conditions.

For the first time, non-flying young birds were observed in July 2006 on the ice protection barriers of A Island. Since then, the nesting of seabirds on islands was assumed every year, but for the first time, it was proved in 2010. Thereafter, the decision was made to monitor them every year.

During these years, the distribution and the ratio of species on the islands have been continuously changing, but annually large numbers of gulls and terns have successful nesting here, which has an impact on their abundance growth in the region, as a whole. This is confirmed by aero-visual records. Figure 12.1.12 is given as an example of a layout of nesting colonies at Kashagan field in 2011 and 2015.

In different years, the composition and abundance of species varied (Table 12.1-4). It should be noted that in 2016 we were unable to visit Kashagan facilities during the nesting period to update the abundance and status of colonies, and the data acquired during the aero-visual survey does not give a full picture.

Table 12.1-4 Information of Birds Nesting at Kashagan Artificial Structures

English name	Latin name	2011	2012	2013	2014	2015	2016
Great black-headed gull	*Larus ichthyaetus*	50	50	300	1000	800	350
Slender-billed gull	*Larus genei*	-	-	30	-	-	-
Caspian Gull	*Larus cachinnans*	600	1 950	1 450	2 200	2 730	940
Common tern	*Sterna hirundo*	3 450	6 400	5 450	1 620	2 900	500
Caspian tern	*Hydroprogne caspia*	15	15	70	10	50	15
Sandwich tern	*Thalasseus sandvicensis*	5 550	3 000	4 150	450	1 100	250
Total pairs		**9 665**	**11 415**	**11 500**	**5 280**	**7 780**	**2 055**

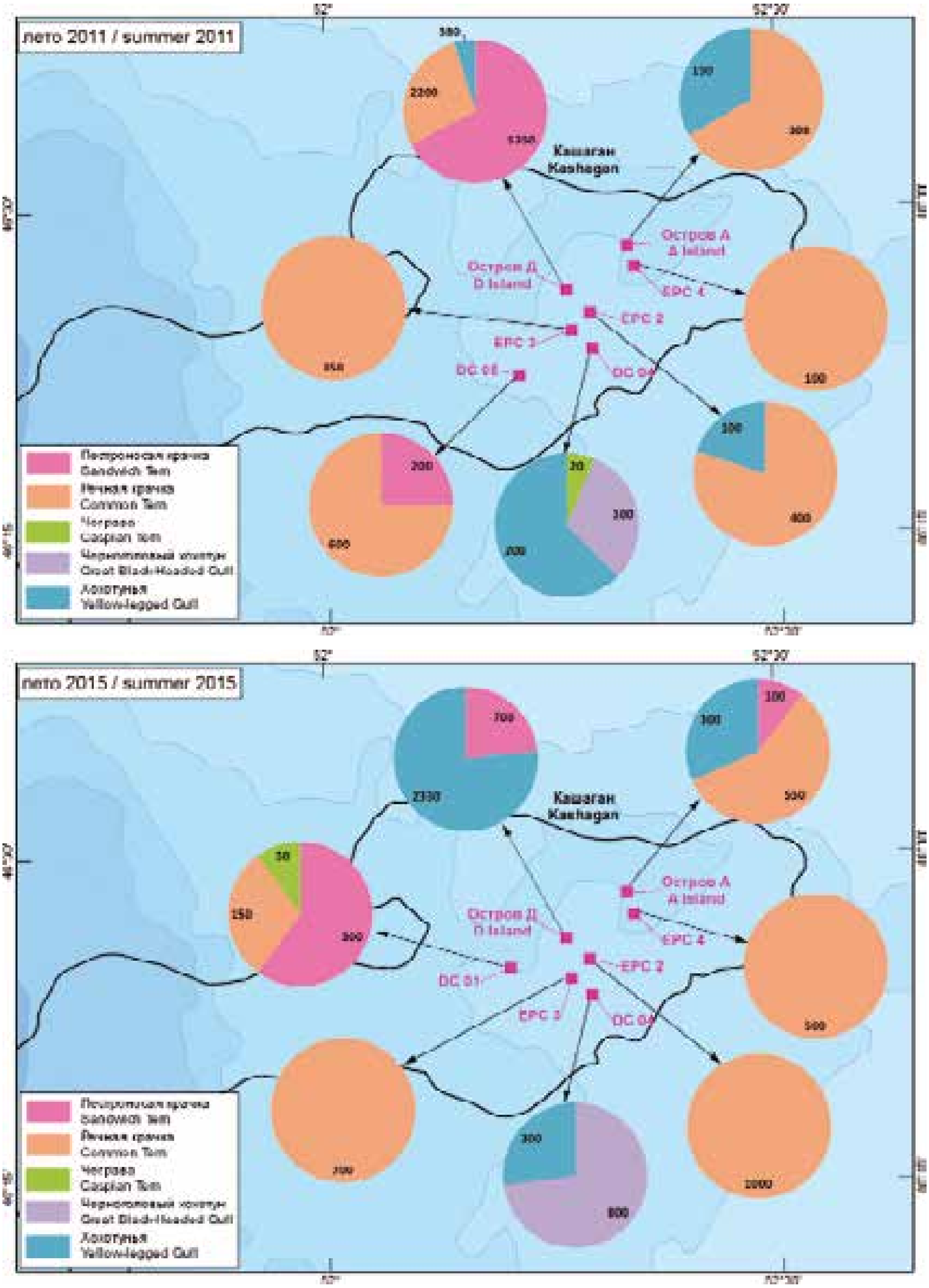


Figure 12.1.12 Layout of Nesting Colonies on the Ice Protected Barriers in Summer 2011 and 2015

Colony of Black-Headed Gulls *(Larus ichthyaetus)* on DC04 Island (Kashagan)

The islands at Kairan and Aktote fields were not involved in intensive operations for several years, and thus they were occupied by gulls and terns. The first records of colonies presence go back to 2009, however, the quality of photographs was poor, thus, it was not possible to define the identity of birds' species. In 2011, the islands were first surveyed from a helicopter. It turned out that over the years of idling, stable colonies of several species of birds were formed on these islands. Since 2011, the islands in Aktote and Kairan areas are surveyed every summer season (Table 12.1-5, 12.1-6).

As it can be seen from the Tables, the islands are almost always inhabited by a huge number of birds; a mixed colony is limited only by the surface area of the island, although birds' abundance has decreased slightly in recent years. Given the regularity of colonies located here, the feed stock in this area, consisting of small fish, is extremely rich. The total abundance of nesting gull birds on these two islands is estimated annually to almost 10,000 pairs. This is a very large colony, even for natural habitats suitable for nesting, and for small artificial structures it is a unique phenomenon.

Table 12.1-5 Abundance of Bird Colonies in Aktote area for 2011-2016

English name	*Latin name*	2011	2012	2013	2014	2015	2016
Slender-billed gull	*Larus genei*	1500	2000	3000	400	-	
Caspian Gull	*Larus cachinnans*	-	-	-	-	-	30
Common tern	*Sterna hirundo*	500	1 000	-	300	-	
Caspian tern	*Hydroprogne caspia*	1 500	700	1 500	1 500	1 500	1 500
Sandwich tern	*Thalasseus sandvicensis*	1 000	1 500	-	200	-	-
Total pairs		**4 500**	**5 200**	**4 500**	**2 400**	**1500**	**1 530**

Table 12.1-6 Abundance of Bird Colonies in Kairan area for 2011-2016

English name	Latin name	2011	2012	2013	2014	2015	2016
Common cormorant	*Phalacrocorax carbo*	-	-	-	-	-	30
Slender-billed gull	*Larus genei*	2 000	2 500	3 000	2 000	1 500	-
Caspian Gull	*Larus cachinnans*	-	-	-	-	-	20
Common tern	*Sterna hirundo*	500	-	-	-	-	-
Caspian tern	*Hydroprogne caspia*	2 000	1 000	1 500	1 500	1 000	1 500
Sandwich tern	*Thalasseus sandvicensis*	1 000	1 500	200	-	-	-
Total pairs		**5 500**	**5 000**	**4 700**	**3 500**	**2 500**	**1 550**

12.1.4 Baseline Birds of the Region

The total abundance of birds in the North-East Caspian Sea as shown above, is quite stable and demonstrates some growth. However, the total abundance consists of the aggregate abundance of individual species. During analysis, we did not note decrease for any species of birds. Most often, there is a fluctuation in abundance, sometimes rather considerable. Let's review the most characteristic and numerous species.

Common Cormorant (*Phalacrocorax carbo*). The abundance of this species is at a high level (Figure 12.1.13). As a rule, in spring and summer, its abundance is not so high and in April and June it usually amounts up to 6,000-7,000 (adult breeding population; at this time, they stay in the area of their nesting colonies). It should be noted that in recent years, the major mass colonies have shifted from the delta areas of the Volga and Zhaiyk Rivers to the Seals Islands area.

Its abundance increases sharply in autumn, when young birds start flying and are included into records together with adults. It should be noted that in autumn cormorants stay in large flocks in feeding grounds, and if their route lies outside the location of one or two such birds' concentrations, then its total abundance is much lower. Therefore,

Colony of the Great Cormorant *(Phalacrocorax carbo)* on the Seals Islands

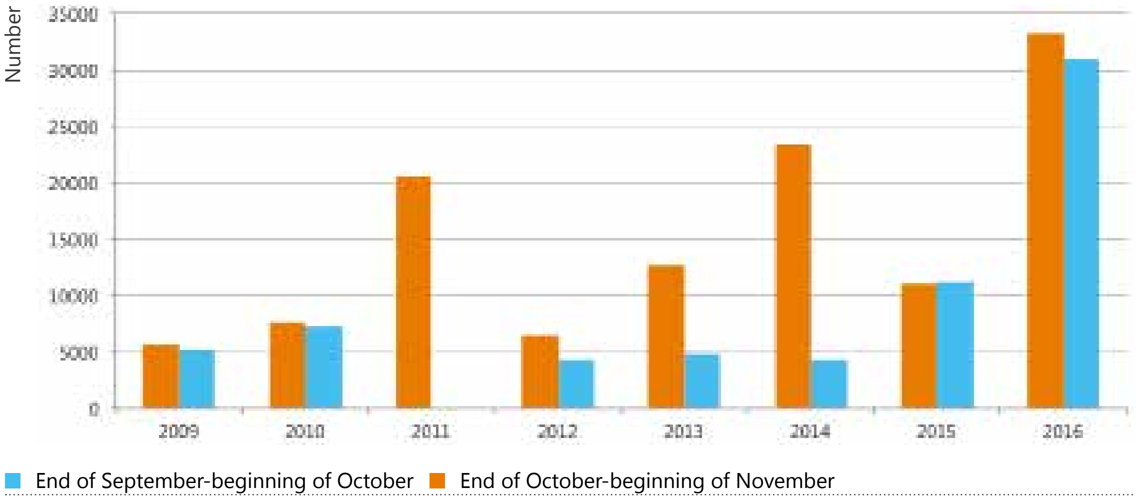


Figure 12.1.13 Great Cormorant abundance recorded in autumn surveys by years

abundance of cormorants in autumn can vary significantly in different years.

Despite a big difference in the data due to peculiarities of autumn surveys of this flock species which is tied to its main feed stock fish, and follows large flocks in this water area, it is obvious that their abundance increases over the years. The main feed stock for cormorants living in the North Caspian Sea is commercial fish (bream, crucian carp, small carp). As opposed to the small cormorant, the feeding biotopes of the great cormorant are not limited to closed delta stretches. These birds use a large area for feeding, sometimes they fly in big flocks far into the open sea, to the grounds rich in fish. Therefore, in future, with an excessive increase in the abundance of great cormorant, which has a significant impact on fish stocks, the issue of its regulation may arise. It should be noted that increase in abundance of great cormorant, which leads to negative consequences in nature, causes a concern in different countries and results in biotechnical measures to limit its population.

Mute Swan *(Cygnus olor)*

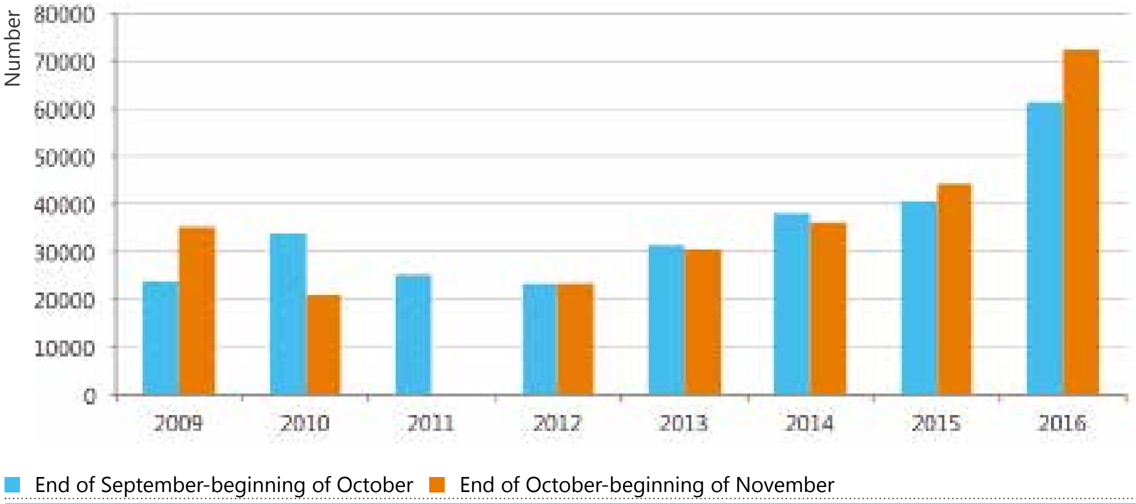


Figure 12.1.14 Mute Swan abundance recorded in autumn surveys by years

Mute swan (*Cygnus olor*). The North Caspian Sea is an extremely important breeding, molting and fattening area for this species. Abundance of the mute swan is at a high level, however, changes over the years can be quite considerable (Figure 12.1.14). Particularly indicative are autumn records, when a breeding population with the grown-up nestlings comes out to the open water from the reeds.

The above graph indicates that population variations represent most likely natural fluctuations. And a sharp increase in abundance in October 2016 is the result of redistribution of the population within the North Caspian Sea.

It should be noted that a century ago this species was not found in the north of the Caspian Sea, and the total abundance of nesting species was

Bald-Coot *(Fulica atra)*

extremely low. This is due to the fact that the Mute Swan was included in the list of hunting species, and at the end of the XIX century, the fishing activities developed in the Caspian Sea, because of down and swan skins [Karelin, 1883]. Following a long break, the first mute swans were recorded in the nesting season in the region in 1938 in the area of Astrakhan Nature Reserve. However, mute swans are encountered in the North Caspian Sea extremely rare, they are not seen every season. When this species was excluded from the lists of hunting birds in the mid-50's of XX century, and with availability of protected areas, its number began to grow rapidly. In the delta of the Zhaiyk River, the nesting population was formed in the mid-1960's. Specific data on its abundance in the references is as follows. During the aerial surveys on July 21-22, in 1983, 70,000 mute swans were counted along the route from the eastern end of the Volga delta to Prorva (part of our regular route) [Krivonosov et al., 1984]. It should be noted that the records were taken in the middle of summer, when young birds were also included into the records, which we do not do in our summer overflights. During another aero-visual survey, on July 19-20, in 1989, 84,500 species were counted (including, 64,600 in the Volga-Ural interfluve [Gistsov, Auezov, 1991]. According to the aerial records of 2000-2007, the number of mute swans in the North Caspian Sea reached 200,000 specimens [Rusanov, 2011].

Mute swans are found in the North Caspian Sea all year round. In addition to the mentioned overflight through this region, they nest here in mass, using reeds, floodlands, etc., with very favorable conditions for growing their youngsters. However, only single families were observed in the delta of the Zhaiyk River due to non-availability of suitable grounds for nesting because of sea recession.

Red-crested pochard *(Netta rufina)*. Red-crested pochard or rufous-crested duck is a baseline species of the North Caspian Sea, which is encountered here in large numbers both in nesting and seasonal migration periods usually at the end of September; red-crested pochard is seen in sufficient numbers in the Volga delta, however, by the end of October they completely leave this area for the Seals Islands, where they stay for wintering in considerable numbers. In autumn 2015, at the end of September, this species was practically missing in the Volga delta; it was in a small number (about 4,000) in the Zhaiyk River delta. However, in the area of the Seals Islands a record number for all years of our observations - almost 50,000 (a previous maximum abundance was 42,500 in mid-October of 2014) was counted. A month later, we counted here almost one and a half times more birds of this species – 74,000. This number seemed to be incredibly high. However, in autumn 2016, this number was higher- in September, 50,000 species were recorded here, similar to the previous year, and in October - over 100,000.

Huge concentrations of rufous-crested ducks were registered in the North Caspian Sea, during the wintering and late autumn seasons. Thus, in January 2005, 120,000 red-crested pochards were counted in the Volga avandelta (G.M. Russanov, personal communication). It is quite possible that unfavorable conditions for existence of birds in the Volga delta in recent years due to extended fires and further drying of reed beds caused by the sea level drop have forced a huge number of mute swans (who usually spend more time in the Volga Delta) to move to a better area of the Seals Islands, and also have squeezed out a major portion of red-crested pochards from these places.

Bald-coot (*Fulica atra*). Bald-coot still remains one of the most numerous birds in the North Caspian Sea; at the same time, during migration not only local birds but also a large number of bald-coots flying from the northern regions are accumulated here.

Counting of bald coot, who stays mainly in reed beds in nesting period is possible only during seasonal migrations and wintering, when they stick to large concentrations in open water. Even in this case, it is often very difficult to notice this species from a helicopter, since a small dark spot on the water could be visible only when this species is frightened by the noise of helicopter, and it takes a run across the water and tries to fly. However, two more conditions are necessary for successful registration of this species: calm water (without waves) and lighting conditions (the sun). Due to its localization, often far from the islands or spits which are subject to our special attention during surveys, we do not sufficiently cover the vast shallow water areas with underwater vegetation that are good feed stock for bald coots. Thus, counting of bald coots is associated with certain difficulties and it is quite possible that this is the reason of considerable differences in the records of this species abundance.

The data for previous years suggests that bald coots fly in a wavy manner - a large number of them is accumulated on suitable biotopes, stays for feeding, and forms fattening clusters, with a sharp weather change flies further to the south. We had noticed such numerous concentrations of birds before their departure, in late September, 2014 (almost 144,000), at the end of October, 2013 (108 thousand), and in early October, 2012 (102,000). In 2016, the number was even higher (Figure 12.1.15). All cases of mass concentrations had common seasonal features – there was no real temperature fall that could be a signal for them to fly to the south for wintering.

12.1.5 Rare and Protected Species of Birds in the Region

European pelican (*Pelecanus onocrotalus*). This species has not been known for a long time (since 1990) in nesting season in the NE Caspian Sea, although it continuously stays in considerable quantities (from several hundreds to 2-3 thousand) in fish areas. At the end of September 2013, 538 pelicans were counted, mostly along the coast of Tengiz, some of them were dark - nestlings of this year, though flying, which indicated the proximity of breeding grounds.

During an autumn overflight in 2014, a proven fact of nesting of this species in the Volga delta was recorded. A large colony of Dalmatian pelican was located here with single species of European pelican nesting in this area. In spring 2015, an epizootic was found in this area, which destroyed the main portion of Dalmatian pelicans (about 74 dead birds are seen in one of our photographs). At the same time, individual pairs of European pelicans continued to stay in the nests, not a single dead bird of this species was noted. It is worth noting that the disease did not affect this species, although European and Dalmatian pelicans are very close. During the autumn surveys it became obvious that the breeding of European pelicans in this colony was successful, there were quite a few flying but completely dark birds in the flocks. In autumn 2016, a large percentage of young dark birds also appeared in flocks of European pelicans, which indicates a successful nesting in this season. In June 2016, we noted two closely located colonies including 30 and 70 pairs, located in the Volga River delta. (Figure 12.1.16).

Dalmatian pelican (*Pelecanus crispus*). The abundance of this species in the North-East Caspian Sea was quite stable. At the end of September 2013, 3,390 Dalmatian pelicans were recorded with the main mass staying in a large colony in Kazakhstan sector of the Volga delta. In September 2014, abundance of Dalmatian pelican was even higher – 4,344 birds with large colonies in the Volga delta. This is a rather high abundance compared to other seasons (1,732 specimens were recorded at the end of September 2009; 894 – in 2010, 2,525 – in 2011, and 1,019 pelicans – in 2012). The reason of such high abundance in previous years was a successful nesting of Dalmatian pelican in several large colonies, especially in the eastern part of the Volga delta. In the middle of October 2014, less than 3,000 Dalmatian pelicans were counted, which most likely indicates migratory movements of these birds.

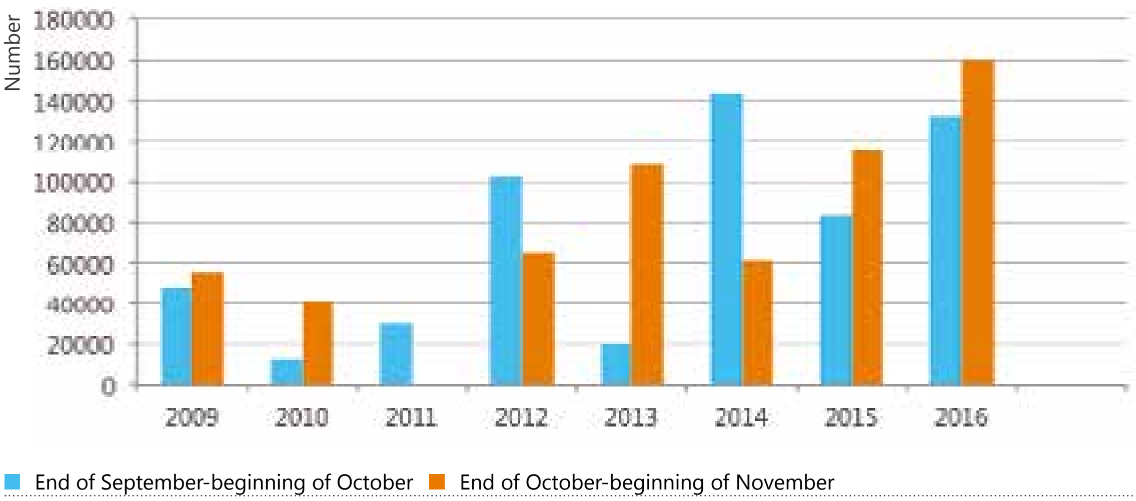


Figure 12.1.15 Bald-Coot abundance in autumn records by years

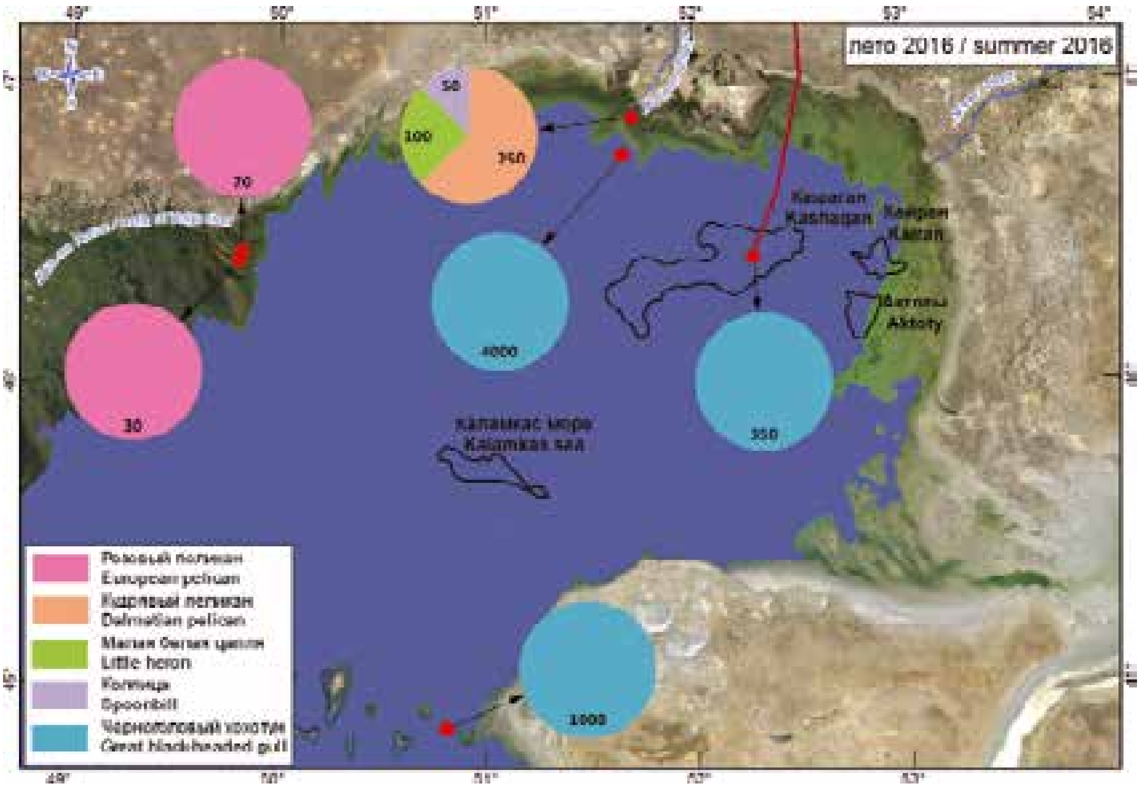


Figure 12.1.16 Colonies of Rare Birds in Summer of 2016

In 2015, an epizooty of these rare birds was noted. It resulted in a sharp decrease of their abundance in the records data – in September, only 1,083 specimens were encountered, and in October – 932 Dalmatian pelicans. It will take more than one year for successful nesting to achieve previous levels of abundance. The results of counts in 2016 confirm fully this assumption. In spring, only 543 specimens were recorded, in June – 353, and in autumn – 2,449, and 496 specimens in two counts. The situation is further aggravated by the fact that their main nesting sites are located in the Volga and Zhaiyk Rivers deltas, and the situation in delta areas is getting worse from year to year. Continuous decrease in sea level, as well as annual fires that destroy nesting areas have contributed into further decrease in abundance. As a result, in 2016 only one colony in the Zhaiyk River delta was found; its number decreased to 250 pairs, although in previous years it was 350 pairs.

Pink flamingos (*Phoenicopterus roseus*). This species is recorded from year to year in the same area - open shallow waters near Komsomolets Bay and along the coast of the Bozashchy Peninsula. However, in recent years (2014-2016) due to a low sea level, most flamingos cannot find suitable conditions in the previous grounds and leave the usual territory for the Seals Islands area and the Mangyshlak Gulf.

The overall picture of the flamingo recorded in autumn is shown in Figure 12.1.17. Such a big difference in the number of flamingos counted, especially at the second stage, depends first of all on the timescale of the second overflight. In 2014, it took place on October 11-12 (for technical reasons, the second overflight took place much earlier than usually at the end of October or the beginning of November), therefore, practically all flamingos still stayed in feeding grounds in Komsomolets Bay and Bozashchy coast. In the years, when the second overflight took place on November 6-8 (2009 and 2010), abundance of this species was minimal, since a major mass had already left for wintering grounds.

Results of records for flamingos depend to a great extent on the time (period) of recording and on the flight route. This is a bird that forms large clusters and if because of flight conditions

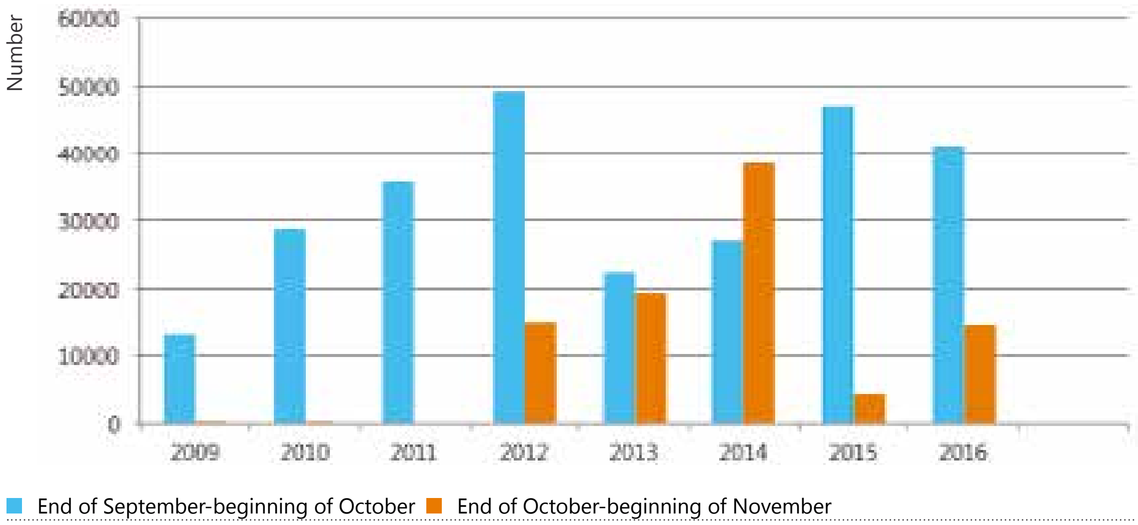


Figure 12.1.17 Abundance of Pink Flamingos in autumn by years

we did not have time to visit the inner parts of Komsomolets Bay, where they stay most time, or somehow we missed the major clusters, this affects the numbers provided in consolidated reports and it cannot be considered as an indication of a real change in the abundance.

Little Egret (*Egretta garzetta*). Little Egrets can be accurately counted under the conditions of aero-visual surveys only in a narrow strip close to helicopter, so the actual abundance is not reflected in the records data. During summer aero-visual surveys, they are most often observed in the area of nesting colonies, where they nest together with other herons, often with small cormorants. The major colonies are located in the delta areas, although in recent years their location has changed, moving further away from the river courses and channels. In 2016, a large mixed colony of water birds was found eastward of the pipeline route, where small white herons also nested. Each year the nesting population is estimated at 600-900 pairs.

Spoonbill (*Platalea leucorodia*). This medium-sized, a large-boned bird has shown an increase in numbers in recent years. Each summer several nesting colonies are noted, although in previous years, only one nesting colony was known – in the Zhaiyk River delta. In 2015, two colonies were mapped – 100 and 250 pairs. In 2016, again only one nesting colony was observed.

Glossy Ibis (*Plegadis falcinellus*). A fairly small ibis, hard to see from a helicopter. At the same time, this is a rather numerous nesting species at the Zhaiyk River delta. The nests of this bird are located in the lower tiers of multi-store colonial formations of small cormorants, various herons, croaks, etc. Continuous flights for feeding are recorded in Peshny Island area, and dozens and hundreds birds fly for feeding to "Tukhlaya Balka" and the western settler. In 2015, at least 500 pairs of Glossy ibis nested in the colony in Peshny Island area. In 2016, they also nested here, however, it is difficult to determine abundance, though visually their numbers do not decrease.

White-tailed eagle (*Haliaeetus albicilla*). This semiaquatic predator is found in the North Caspian Sea all year round. In spring and summer, it is not numerous, because only nesting pairs stay along the Volga channels, occasionally – in the Zhaiyk river, alongside with young immature birds.

By autumn, their abundance increases due to concentrations of wetland fowl, which constitutes a significant part of the menu for this species, and because fishermen leave a lot of fish behind them. Following an abnormally high abundance in autumn season 2009, when about 1,500 eagles were counted in November, according to our records the number of birds has been stabilized (Figure 12.1.18). Such a record number of registered birds is explained by unique weather conditions during the survey, i.e. after a warm and long autumn, frost hit (17°C) on the day before the survey (November, 6), and in two days all shallow bays and a considerable part of the

Flamingo *(Phoenicopterus roseus)*

open water area was covered with ice. The eagles staying in flocks of 50-80 specimens were found exactly on such first ice. It was absolutely not typical for this large predator. The impact of the second overflight timescale is evident in the below diagram. During the years with the late timing of the second overflight (2009-2011) when counts were conducted on November 6-8, abundance of white-tailed eagles was the highest, as they arrive to the coast of the Caspian Sea with the onset of a real cold weather.

White-tailed eagle, like other predators, concentrates at sources of available food, so it can be often seen near fishermen's camps, close to large clusters of waterfowl, and in winter in pupping grounds of the Caspian Seal. In winter time, this species is regularly observed on the eastern coast between Tup-Karagansky Bay and Kuryk port.

Great black-headed gull (*Larus ichtyaetus*). This species is rather prosperous in the North Caspian Sea, nesting here in huge colonies and having a fairly high abundance (Figure 12.1.19). The records indicate a steady increase in abundance of this gull based on long-term observations. It can be explained by successful breeding seasons and a sufficient feed stock which includes mainly small fish.

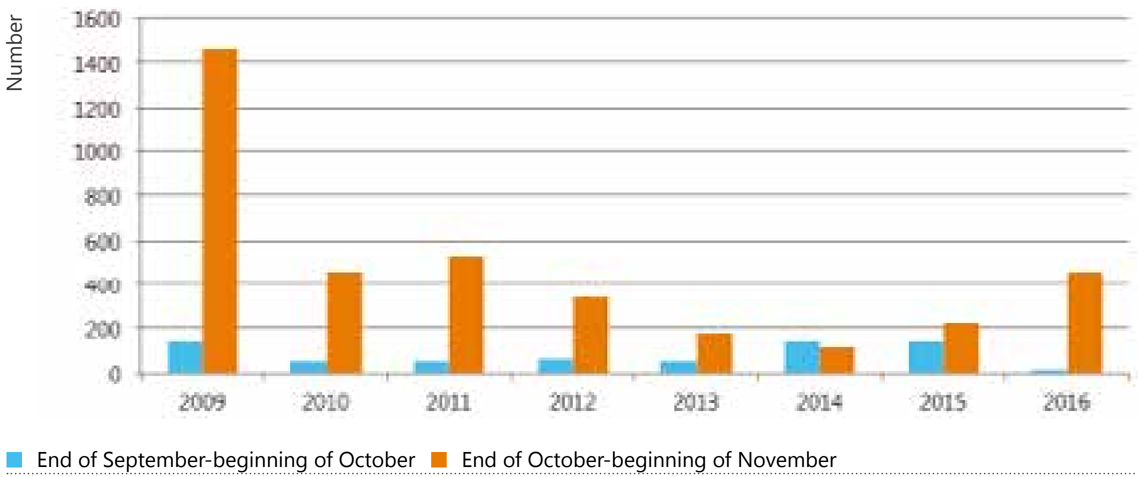


Figure 12.1.18 Abundance of White-Tailed Eagle in autumn by years

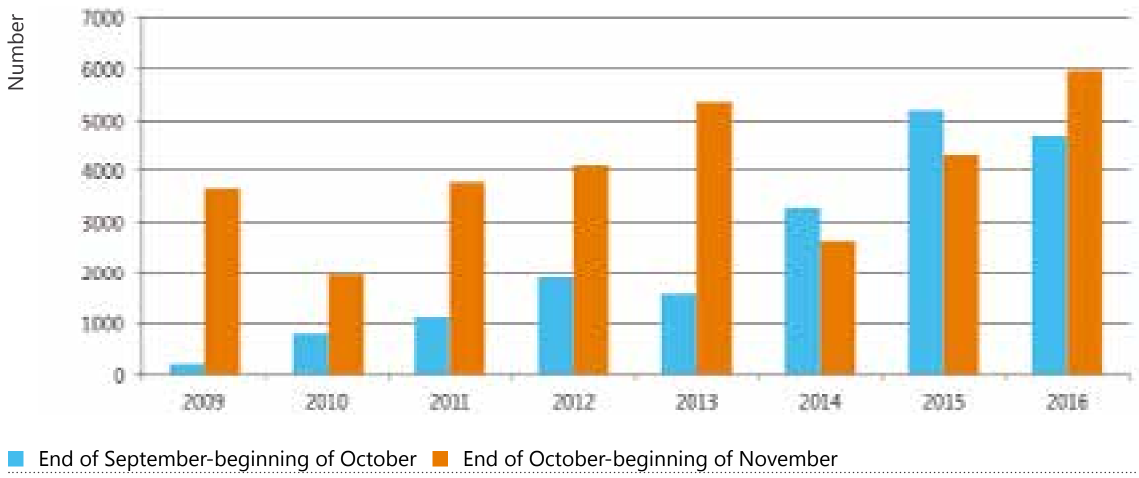


Figure 12.1.19 Great Black-Headed Gull in autumn by years

12.1.6 Current Status of Ornithofauna and Factors Impacting Thereon

The data provided in this Chapter shows that the North-East Caspian avifauna is in a stable state. Abundance of individual species sustains quite significant changes, however, it is variable and often has a fluctuation nature, and directly depends on natural phenomena – seasonal weather conditions and a drop in the sea level. Due to continuous drop of the sea level during the period 2006-2016, the coastline in the northern shallow part of the Caspian Sea, has moved inland up to 15-30 km. Former bays (near Zhambay, Zaburuniye), which had previously provided excellent conditions for gatherings of birds during migration time, have dried by 80-90 %, turning first into wet mud, and then covering with salty soil. Currently, land grasses are growing in the areas that used to be shallow waters. Several kultuks (shallow bays deeply penetrating into dry land) practically ceased to exist, and now have the water depth of only 10-15 cm. Their complete drying-up is a matter of 1-2 years. Reed beds on dried ground die and are exposed to burning (most often intentionally by local residents). Thus, habitats suitable for birds near the northern coast of the Caspian Sea have decreased significantly. Similar changes are taking place on the western coast of Dagestan.

In addition to natural causes that have a negative impact on the well-being of habitats suitable for birds, there is a number of factors of anthropogenic nature. First of all, this is burning of reeds, especially in the vicinity of delta areas, where large colonies of tibiae and copepods are located. The site of fire is restored to its normal state in several years. During this period the birds are forced to look for other places for reproduction. The other important factor is poaching. During aero-visual surveys, gross violations of the nature use rules were repeatedly noted - violation of the established hunting periods, fishing during the spawning season, hunting from boats, etc.

Another factor impacting the population of birds, especially in the Zhaiyk River delta, is a better living standard of the population. It resulted in increase of the load on water ways. Movement of motor boats and other vessels is becoming more intense. During the surveys, movements of quadrocycles and motodeloplanes in reed beds were noted. This leads to a higher disturbance factor. Annually, we note a decrease in abundance of birds in the Zhaiyk River delta; the nesting colonies are located more and more farther from the river, although the deltas of rivers around the world are the most popular breeding place for water birds.

The above described factors have led to the fact that more and more migrants began to move to the Seals Islands area. Density of birds during autumn migrations is extremely high there - up to 22,000-27,000 specimens per 30 km^2. Under current shallowing conditions the depth in these wide areas is such that the bottom is not exposed; well-warmed shallow water has highly developed underwater vegetation, and many islands and spits provide a shelter and rest places for birds. In addition, this area is not subject to a high factor of disturbance. The area is included in the International Register of Key

Bird Areas (IBA) as globally significant, which is confirmed by our surveys, and is subject to protection at the international level. However, poaching in this area is recorded, and the number of hunters' camps is increasing. It is this kind of activity of the local population that can lead to decrease in abundance of birds, however, other nature users of the North Caspian Sea would be blamed for that. It is necessary to draw attention of environmental institutions to enhancement of protection of this unique area.

Observations at Kashagan offshore facilities directly during construction and development phases allow concluding that no significant impact on the avifauna is expected under routine operations. It is necessary to note a positive impact of the existing offshore facilities in Kashagan - nesting of seagulls and terns on the ice protection barriers for a number of years has resulted in increase of abundance of these species throughout the entire North-East Caspian Sea area. Tentative hazardous factors can include a continuously burning flare on D Island and night illumination of offshore facilities which attracts night migrants thereto. Minimization of these factors impact is now under study.

Review of long-term monitoring data for avifauna makes evident that no serious environmental changes have been revealed to date because of presence of Kashagan artificial structures in the North Caspian Sea. This is confirmed by a favorable condition for a number of baseline bird species. They include both fish-eating and herbivorous species, which in its turn means preservation of their feed stock at a high level. However, the results of monitoring (conducted under control and with participation of representatives of environmental authorities) are often contrary to the public perception (artificially created negative attitude to the fact of the very existence of Kashagan field). Meanwhile, the majority of complaints about the disappearance of seals, fish and waterfowl are either groundless or have other causes (incidental catch of seals when poaching for sturgeon, hunting with violation of rules and standards for hunting, fishing during spawning, etc.).

Conclusion

The value of high quality monitoring is in continuous control of an actual situation in a large area of coastal biocenoses in the North-East Caspian Sea using the unified methodology. This region is of the utmost importance for millions of waterfowl and semi-aquatic bird species that gather here from a significant part of the northern half of the Eurasian continent - from Scandinavia to the tundra zone of Siberia.

Despite the ongoing water level drop in the Caspian Sea and drying of large areas suitable for water birds, the Caspian Sea continues to play a leading role in the well-being of nesting and migratory birds. This is confirmed by establishment of 5 IBA of international importance in its territory and its approval as "Wetlands of the Republican Significance" by Order No. 273-ө dated 6 September, 2013 of Minister of MEP.

The entire territory of the Caspian Sea from the Volga Delta to the Seals Islands and Mangyshlak Bay is a single ecosystem, reacting to changes of conditions in this area by redistribution, namely, in the Kazakhstan sector of the North- East Caspian Sea, which is annually confirmed by the data of our observations.

Changes in abundance of individual species are of a fluctuation nature, and do not indicate any obvious trends for decrease.

Observations at Kashagan field facilities confirm that artificial islands do not play a major role for migrants. The number of birds making a forced stop on the artificial islands where the observations were conducted, is insignificant, and even in non-routine situations this cannot have an impact on abundance of any observed species.

No negative impact of NCOC N.V. activities on abundance and distribution of nesting and migrating birds during the entire monitoring period has been revealed. All changes are caused by natural (water level drop) and anthropogenic factors (fires, poaching, a higher disturbance factor due to increased human activity).

12.2 Birds Distribution and Abundance according to Results Monitoring Surveys performed with Use of Scientific-Research Vessels.

Methodology and Input Data

Birds surveys in the warm period of the year (spring, summer, autumn) have been arranged by NCOC N.V. since autumn 2012 in the framework of industrial environmental monitoring, according to the requirements of the RoK legislation. The following fields have been surveyed annually using the scientific- research vessels (SRV): Kashagan, Aktote, Kairan, Kalamkas-Sea (hereinafter Kalamkas) and Oil field pipeline route (Chapter 2. Figure.2.2).

The bird counts were conducted at each monitoring station continuously during 30 minutes. The highest point on the vessel was selected to ensure an all-round view of the water surface and air space above it within a 500-meter range. Observations were conducted using 10 and 30-fold binoculars. When detecting single individuals or flocks of birds flying or sitting on the water, they were examined through binoculars and the information was recorded with digital dictaphone. Species identity, numbers, direction of flight, the way of staying on water, and behavior were recorded. If possible, pictures of all birds' species were taken with a digital camera (70-300 mm camera lens, or a 20-fold zoom) and then examined thoroughly on computer to adjust the species identity and abundance.

During the entire survey period from autumn 2012 to autumn 2016, 2,455 hours of visual observations were spent at 4,489 sampling stations, 193,127 birds were registered (Table 12.2-1). The birds landing on support vessels and SRV were registered as well.

12.2.1 Distribution and Numbers of Birds in Surveyed Water Areas of the North-East Caspian Sea

240 species were recorded in the North-East Caspian Sea area, mainly at the offshore facilities locations and along the Oil field pipeline route, (Annex 8, Table A2). They included waterfowl, semi-aquatic and land birds belonging to 18 systematic orders (Figure 12.2.1), [Environmental Monitoring Reports,]Autumn 2012 - Autumn 2016] and 19 rare species registered in the National (RoK Red Book, 2010) and the International Red Book: Dalmatian pelican (*Pelecanus crispus*), European pelican (*Pelecanus onocrotalus*) little egret (*Egretta garzetta*), spoonbill (*Platalea leucorodia*), glossy ibis (*Plegadis falcinellus*), American flamingo (*Phoenicopterus roseus*), whooping swan (*Cygnus cygnus*), Common Scoter (*Melanitta fusca*), fish-hawk (*Pandion halyaetus*), steppe eagle (*Aquila nipalensis*), imperial eagle (*Aquila heliaca*), white-tailed eagle (*Haliaeetus albicilla*), peregrine (*Falco peregrinus*), saker falcon (*Falco cherrug*), barbary falcon (*Falco pelegrinoides*), gray crane (*Grus grus*), bustard (*Tetrax tetrax*) great black-headed gull (*Larus ichthyaetus*) and black-bellied sandgrouse (*Pterocles orientalis*).

Besides the birds of the wetland complex (102 species), land inhabitants (138 species) were observed in this sector of the sea during migration and summer nomadic migration They are representatives of desert, steppe, forest, mountain and anthropogenic landscapes. The

Table 12.2-1 Number of Stations and Registered Birds by Years and Seasons

Year	Spring Date	Spring Stations	Spring Birds	Summer Date	Summer Stations	Summer Birds	Autumn Date	Autumn Stations	Autumn Birds	Total Stations	Total Birds
2012	-	-	-	-	-	-	12.11 - 01.12	78	947	**78**	**947**
2013	05.04 - 30.05	383	36433	15.06 - 27.07	389	15884	03.10 - 04.11	411	7544	**1183**	**59861**
2014	03.04 - 25.05	404	36571	14.06 - 05.08	402	15212	22.09 - 03.11	398	11467	**1204**	**63250**
2015	15.04 - 27.05	431	2519	25.06 - 20.08	426	15806	20.09 - 30.10	431	2607	**1288**	**44328**
2016	15.04 - 14.05	243	10910	25.06 - 24.07	240	7266	20.09 - 19.10	253	6565	**736**	**24741**
Total	**-**	**1461**	**86433**	**-**	**1457**	**54168**	**-**	**1571**	**29130**	**4489**	**193127**

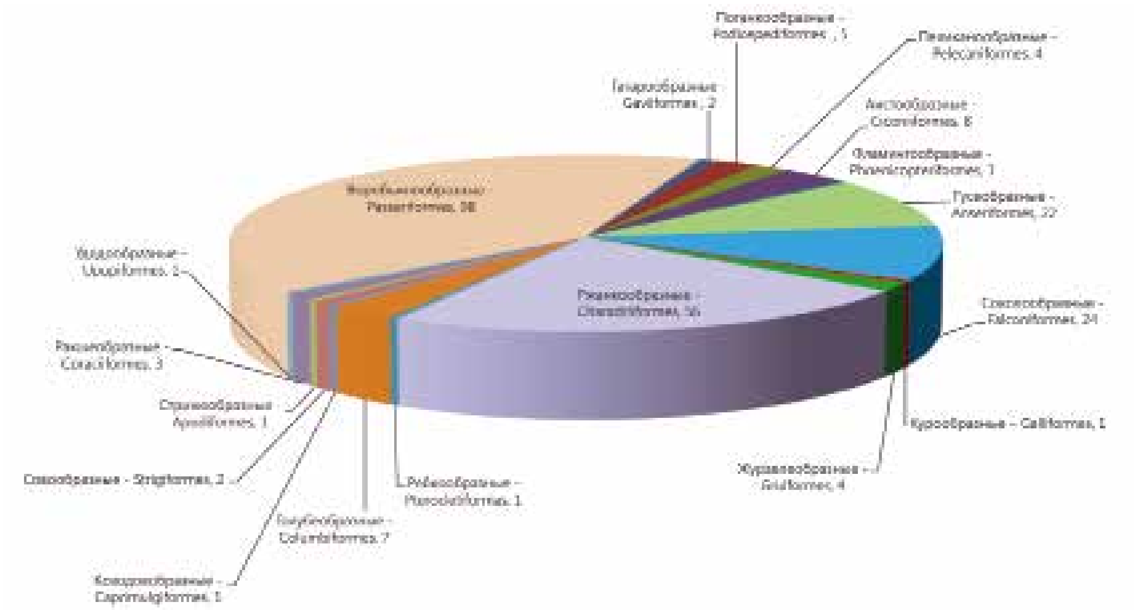


Figure 12.2.1 Systematic Structure of Birds Inhabiting the North-East Caspian Water Area and Company's Offshore Facilities

dominant species in this group were perching birds *(Passeriformes)* – 98 species as well as birds of prey *(Falconiformes)* – 24 species.

Along the Oil field pipeline route, during offshore environmental surveys in 2013-2016, (spring, summer, autumn), 97 species of birds were recorded, including loons – 1, grebe – 3, pelican – 4, stork – 5, Phoenicopteriformes – 1, anseriformes – 8, birds of prey – 5, Gruiformes – 1, wading birds – 31, Columbiformes – 1, Strigiformes – 1, coraciiformes – 1, Upupiformes – 1 and perching birds – 34 species. They include 6 specially protected species: European pelican, glossy ibis, American flamingo, Common Scoter, white-tailed eagle, and great black-headed gull.

The water area under review from D Island to the coast, 4,000 m wide is a natural habitat for birds, since it does not have any surface facilities. 7 species with occurrence of 50 to 100 % are referred to the baseline category. In all seasons they were: Herring gull *(Larus cachinnans)* and great black-headed gull *(Larus ichtyaetus)*; in spring-black-headed gull *(Larus ridibundus)* and sandwich tern *(Sterna sandvicensis)*, in summer - common tern *(Sterna hirundo)*, and in autumn - slender-billed gull *(Larus genei)* and common gull

Herring gull *(Larus cachinnans)*

Great black-headed gull *(Larus ichthyaetus)*

Common tern *(Sterna hirundo)*

Sandwich tern *(Thalasseus sandvicensis)*

(Larus canus) are joining them.

In the water area of Kalamkas field, 113 species of birds have been recorded, including 1 species of loons, grebe – 2, pelicans– 2, stork – 3, anseriformes – 5, bird of prey – 9, fowl-like birds – 1, wading birds – 26, Columbiformes – 1, Caprimulgiformes – 1, Strigiformes – 2, Apodiformes – 1, coraciiformes –2, Upupiformes – 1 and perching birds – 56 species, and 3 specially protected species registered in the Red Book of the RoK (2010): glossy ibis, flamingo, Common Scoter, white-tailed eagle, great black-headed gull, barbary falcon (*Falco pelegrinoides*).

Currently, the habitat conditions at this field are also natural. 9 baseline bird species were recorded here. The most frequent in all seasons was herring gull with a common tern occurred here in spring, summer, and once in autumn 2016. Great black-headed gull was more frequent in spring, in summer its frequency of occurrence decreased to 7.5 – 27.7 %. During the whole survey only 1 bird was recorded here in autumn. In summer, the baseline species were white-winged tern (*Chlidonias leucopterus*) and black tern (*Chlidonias niger*), and in autumn - common gull, sky lark (*Alauda arvensis*), and white wagtail (*Motacilla alba*).

12.2.2 Distribution and Trends in Nesting Species Abundance at Offshore Artificial Facilities

Besides the observation of birds (spring, autumn 2008-2016), conducted by ornithologists on artificial islands described earlier in Section 12.1, observations within the framework of industrial environmental monitoring have been conducted since autumn 2012 [Environmental Monitoring Reports, Autumn 2012 - Autumn 2016].

According to results of observations conducted from the SRV, 207 bird species were recorded in Kashagan water area including loons – 2, grebe – 3, pelicans – 2, stork – 5, flamingo – 1, anseriformes – 20, bird of prey – 21, fowl-like birds – 1, Gruiformes – 3, wading birds – 46, Pterocletiformes – 1, Columbiformes – 6, Caprimulgiformes – 1, Strigiformes – 2, Apodiformes – 1, coraciiformes – 2, Upupiformes- 1 and perching birds – 89 species. The registered species also included 14 specially protected species, i.e. European pelican, glossy ibis, common flamingo, whooping swan, Common Scoter, steppe eagle, imperial eagle, white-tailed eagle, peregrine, saker falcon, gray crane, bustard, great black-headed gull and black-bellied sandgrouse.

There are no permanent inhabitants in the open sea areas, the only species encountered here during the year, including winter, is the white-tailed eagle. At the same time, in recent years, the seabirds have been using the ice protection barriers close to artificial islands in Kashagan East and the stand-alone islands in Aktote and Kairan area as a nesting ground.

During the entire survey period at Kashagan field several quite numerous breeding colonies of herring gull, sandwich tern and common tern were located on the ice protection barriers close to islands D and A, EPC (2; 3; 4) and DC05 as well as on DC01 and DC10 Islands. A colony of great black-headed gull was observed on DC04 island.

Depending on weather conditions, feed stock and disturbance factor (during construction) that have impact on the time and success of nesting, a change in the numbers of these species by years

Spring Summer

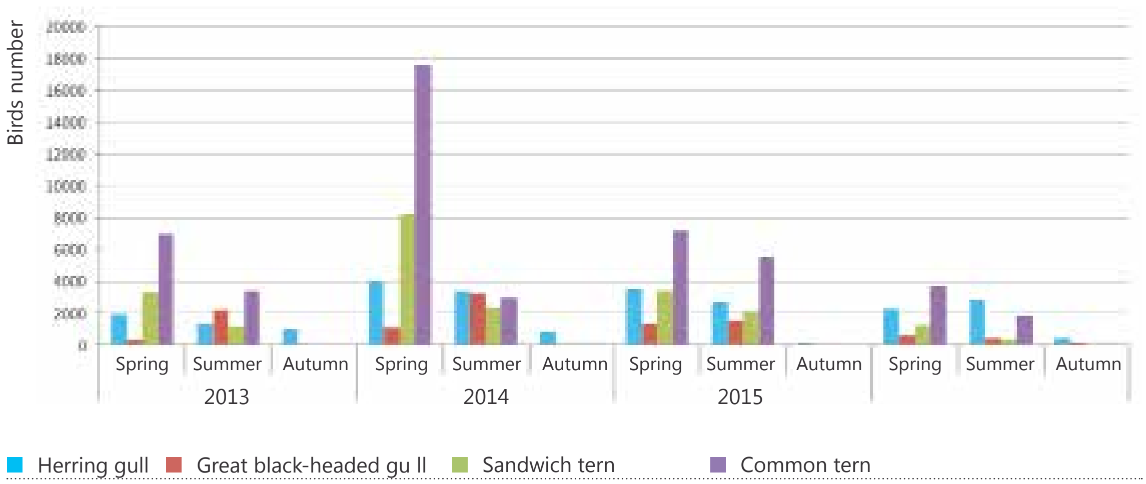


Figure 12.2.2 Trends in Numbers of Nesting Species by Years and Climatic Seasons. Kashagan, 2013-2016.

and seasons has been observed (Figure 12.2.2).

The dominant species in all spring and two summer seasons was a common tern. In spring 2013 and 2015 its number was about 7,000, and in 2016 it decreased to 3,700. The largest number was observed in spring 2014, when favorable weather conditions were formed for mass migration of the common tern to northern habitats. Along with nesting birds in Kashagan, 17,517 birds of this species were recorded. The second in terms of numbers was sandwich tern; the dynamics of its number by years and seasons coincides with the common tern. In spring 2013 and 2015 its number was about 3,400, and in 2016 it decreased to 1,200 specimens. The largest number was also observed in spring 2014 – 8,200 specimens. Migration of terns begins early, when nestlings are starting to fly and live independently and usually by the end of summer they are almost all gone. In autumn there are almost no birds left, the remaining birds stay in single or very small (2-4 birds) flocks that have completed their re-nesting.

The number of herring gull in 2013-2015 had been decreasing from spring to autumn from 1,900–3,500 to 1,400-150 specimens and only in 2016 there was a slight increase by 600 birds recorded in summer. The number of black-headed gulls in 2013-2015 had been increasing from spring to summer (by 1.1-6.4 times) and had significantly decreased in autumn (up to 6-70 birds), and in summer 2016 the abundance had decreased by 150 birds with a further decrease in autumn.

Aktote and Kairan islands are located in the shallow coastal zone. The major part of islands' flat surface is covered with fine loose soil and some places are overgrown with reeds and grassy plants; thus, the above factors and location of islands provide favorable conditions for nesting of slender-billed gull (Larus genei), Caspian tern (Hydroprogne caspia), sandwich tern, and common tern.

The following 82 bird species were registered in Aktote water area: loons – 1, grebe – 4, pelicans– 3, stork – 6, flamingo – 1, anseriformes – 8, bird of prey – 5, Gruiformes – 1, wading birds – 28, Strigiformes – 1, Apodiformes –1, Upupiformes - 1 and perching birds – 23 species. 6 specially protected species were recorded and included European pelican, Dalmatian pelican, little egret, spoonbill, peregrine, and great black-headed gull.

Slender-billed gull and Caspian tern were the dominant nesting species. The river and the variegated terns nesting also here were registered in smaller numbers. (Figure 12.2.3)

A significant decrease in numbers was observed for all species under consideration from spring to summer, except for 2013, when the numbers of slender-billed gull remained at a high level in summer, while the numbers of Caspian tern and sandwich tern had even increased. In autumn seasons 2013 – 2016, there were no nesting species in this area or single migrating birds were observed. The number of slender-billed gull in spring 2013 and 2015 was high; in 2014,

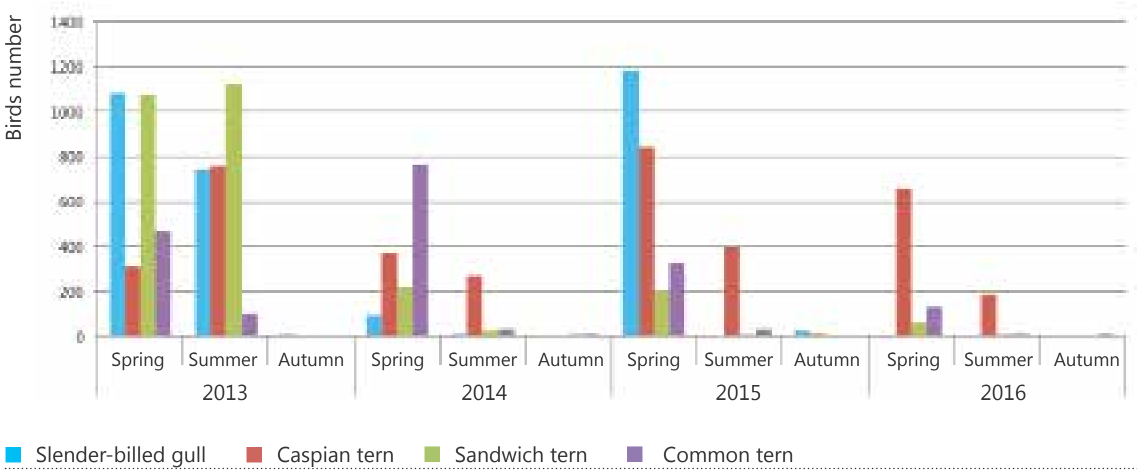


Figure 12.2.3 Trends in abundance of nesting species by years and climatic seasons. Aktote, 2013-2016.

it decreased by 13 times and in all seasons 2016, such species was not present in the field.

The following 89 bird species were recorded in Kairan water area: grebe – 4, pelicans – 3, stork– 5, flamingo – 1, anseriformes – 5, bird of prey – 9, wading birds – 31, Columbiformes – 1, Strigiformes – 1, Upupiformes – 1 and perching birds – 28 species, including 5 specially protected species: European pelican, Dalmatian pelican, glossy ibis, American flamingo and great black-headed gull.

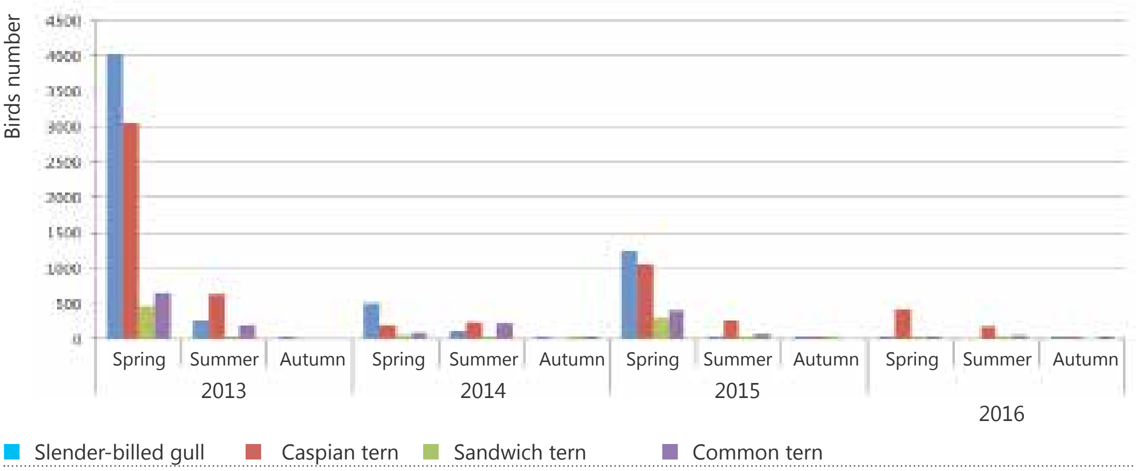
Similar to Aktote Slender-billed gull and Caspian tern were the dominant species in Kairan. Common tern and Caspian tern nesting here were registered in smaller numbers (Figure. 12.2.4).

The numbers of nesting species in spring had been changing with increase and decrease every other year. It was higher in 2013 and 2015 and then lower in 2014 and 2016. All species under consideration had a significant decrease in numbers from spring to summer, except for summer 2014, when the number of Caspian tern increased by 34 birds. In all autumn seasons in the period 2013-2016 no species had been observed in the field, except for single migrating birds.

The number of slender-billed gull and Caspian tern in spring 2013 was very high (10,816 and 3,047 birds, respectively), and then it decreased significantly. There was also a general trend in reduction of slender-billed gull, sandwich tern, and common tern numbers. In spring 2016, only 2, 37 and 38 birds of these species were registered, respectively. There was no nesting of slender-billed gull.

Slender-billed gull (*Larus genei*)

Caspian tern (*Hydroprogne caspia*)



Note: *the diagram of spring 2013, due to the technical reasons, the number of slender-billed gull was reduced from 10816 to conventional value of 4000.*

Figure 12.2.4 Trends in abundance of nesting species by years and climatic seasons. Kairan, 2013-2016.

In spring 2014, large cormorant (Phalacrocorax carbo) started nesting on some hanging fenders of the island. In spring 2015, their nests were located along the whole island perimeter.

12.2.3 Birds Migration across the North-East Caspian Sea

The Siberian- Black sea- Mediterranean migration route is one of major routes in Eurasia and lies through the North Caspian Sea (Fig.12.1.5). In 2001-2006, according to results of onshore surveys and aerial surveys of coastal zone, 292 bird species were recorded on the coast of the North-East Caspian Sea and Seals Islands. They included 112 nesting species, 76 – wintering, and 104 migrating species (Gistsov et al., 2014).

Observations from SRV, conducted by NCOC N.V. in 2012-2016 allowed getting new data, which is supplementing the previous data related to features of different bird groups migration across the water area.

Large Cormorant (Phalacrocorax carbo). Nesting on Kairan Island

The relatively small width of the Caspian Sea is not a significant obstacle for waterfowl and semi-aquatic as well as for many land birds crossing it from the north-east to south-west in autumn and in the opposite direction in spring [Erokhov et al., 2007; Erokhov et al., 2015]. 240 species were registered (Figure 12.2.1). Charadriiformes, Anseriformes, as well as all representatives of Kazakhstan avifauna such as loons, grebe and pelican were dominant in the water- wetland species complex, while perching birds and birds of prey dominated in land species complex.

The birds of Kazakhstan northern regions and Western Siberia, as well as the inhabitants of tundra zone, the Arctic coast and the northern islands of Russia can be encountered during migration across the Caspian Sea: red-throated diver, bluebill, long-tailed duck, black-bellied plover, turnstone, spotted redshank, northern phalarope, little stint, Temminck's stint, dunlin, chickweed, Arctic skua and pomarine skua, glaucous gull, kittiwake, and lesser black-backed gull. The typical forest species such as nutcracker, wren, goldcrest, and common creeper were also migrating across the sea.

In the second half of May three young Mediterranean gulls were recorded at Kashagan and Kalamkas fields. Mediterranean gull is a partially migrating bird. Earlier, several birds were observed in July 1951 and 1952 in Bautino and on Mangistau islands in Kazakhstan sector of the North Caspian Sea [Gladkov, Zaletayev, 1956].

In general, the time of spring and autumn migration over the water area depends on climatic conditions of each year and is similar to the time for land migration: spring migration - from February to May, autumn migration from late July to November. There are two forms of migration across the sea: trophic migration - for loons, grebes, pelicans, cormorants, and some representatives of anseriformes, skuas, gulls, terns, northern phalaropes; and a transit migration for all other species. Land birds usually migrate at night. Single or small flocks of these species can be seen during the day time. The intensity of migration across the water area depends on weather conditions. During daylight hours and calm sea, the migration practically stops, at weak wind it is also not large (from 3-8 to 25-43 specimens / hour). In windy weather the migration increases (68-79 specimens / hour) and becomes more intensive during a cold weather (1,633 specimens / hour). Migrating numbers and intensity of flies become higher during cyclone events; and in rainy and snowy weather the migration stops. The morning peak of migration is from the dawn till 11 o'clock and makes 80-85 % of daily numbers. At noon time from 12 to 15 o'clock the migration comprises less than 5 % and reaches 10 % in the evening. The main direction in spring is eastern, north-eastern (cumulatively 91 % of birds), in autumn – western and south-western (86 % of birds).

DURING MIGRATION PERIODS MANY SPECIES OF WATER-WETLAND COMPLEX AND LAND BIRDS USE THE ARTIFICIAL OFFSHORE FACILITIES, SUPPORT VESSELS, SRV AND OTHER WATERCRAFTS, AS SMALL "LAND AREAS" TO GET SOME REST AND FOOD.

The time spent on SRV can be from several minutes and hours (mostly large birds) to several days (small perching birds). More than a hundred species of birds were recorded on the SRV: herons, cormorants, day and night predators, sandpipers, gulls, terns, turtledoves, quails, and almost all perching birds.

Mediterranean gull *(Larus melanocephalus)*

Conclusions

The majority of birds migrating along the Siberia-Black Sea-Mediterranean route (240 species) use the Caspian Sea water area for flyover.

The artificial offshore facilities are an attractive place for both nesting species and seasonal migrants. This is particularly evident at Kashagan offshore facilities where the number of recorded species (207) is twice as higher as on other sites.

Gradual increase in the number of species nesting on offshore facilities has been observed. For example, small tern and Caspian tern started nesting on Kashagan DC10 Island and the big cormorant - on Kairan island.

In addition to offshore facilities, hundreds of bird species use vessels and other watercrafts for resting and feeding during seasonal migration.

In the survey period, no significant negative impact on the avifauna from offshore facilities and vessels had been recorded.

CONCLUSION

A necessary condition for biodiversity preservation is availability of a monitoring system to control the state of hydrobionts and the quality of the abiotic environment. Offshore environmental monitoring conducted by NCOC N.V. in the Contract Areas (water areas) of Kashagan, Kairan, Aktote and Kalamkas-Sea fields, as well as along the Oil field pipeline route, allowed assessing the current state of all surveyed components of the marine environment - ambient air, sea water, bottom sediments, plankton, benthos, ichthyofauna, avifauna, the Caspian seal, etc.

Arranged and conducted environmental surveys included simultaneous measurements of a large number of environmental parameters (hydrological, hydrochemical, geochemical, hydrobiological, and ichthyological) at the unified stations' network.

In 2013, the Company started monitoring surveys based on the unified Industrial Environmental Control Program (IECP), in accordance with the requirements of Article 132 of the RoK Environmental Code and the Rules..., 2012 and 2014. When the Rules..., 2012 came into force and based on current Rules..., 2016, the types of observations and number of environmental monitoring stations have increased. The monitoring has been conducted in all climatic seasons. The survey area of the Caspian Sea's water area has been expanded as well.

Environmental monitoring in 2006–2016 made it possible to assess potential impacts from conducted operations on environmental components related to offshore field developments.

It should also be noted that the below results of the environmental monitoring are closely related to ongoing changes in some environmental factors, which play an important and major role in the Caspian Sea's ecosystem functioning. They include:

— Increase in the average annual air temperature for the last decade (2007–2016) is 0.44 °C in Atyrau region and 0.48 ° C in Mangistau region.

— Nature of the ice cover. In mild winters, the North Caspian Sea is covered with ice during 3–4 months, in anomalously cold winters- up to 4–6 months. There were only two cold winters during the survey period — the winter of 2007–2008 and 2011–2012.

— Shallow waters in the North Caspian Sea and the continental climate in the region cause seasonal changes in the water temperature. During the monitoring conducted in summer in Kashagan area, the temperature exceeding 27-28 °C (max. 31 °C) was recorded in the surface layer.

— The sea level fluctuation. There is an evident tendency in the sea level drop. The value of the level drop in 2006-2016 was approximately 1 m.

— Pollutants entering the sea with the Volga River inflow remain the main source of the North Caspian Sea pollution. The Volga River's inflow carries hundreds times more petroleum products, 4 times more SSAS, 1.6 times more copper, and 2.3 times more nickel than the Zhayik River's inflow.

Ambient Air. Concentrations of all observed pollutants at Kashagan, Aktote, Kairan, Kalamkas fields were lower than the MPCm.o.t. at all stations. Concentrations of sulphur dioxide, nitrogen oxides, hydrocarbons were recorded as peak values and had irregular nature. This was related both to seasonal changes in the atmosphere, and the impact from operational activities. A certain impact from the operational activities was noted at Kashagan at level 1 stations, which are located closer to the offshore facilities.

The impact on the ambient air state from wells testing can be assessed as local. It was limited to a 10 km zone from the flaring unit and concentrations did not exceed MPCm.o.t. The mode of fluid flaring is quite efficient as evidenced by the absence of ash emissions in the exposed area.

Increase of carbon oxide concentrations was recorded almost at all stations, including the baseline stations. The maximum concentrations of carbon oxide were also recorded in areas located outside the facilities in operation or under construction. In order to understand the reasons for increase in carbon oxide concentrations it is necessary to conduct more extensive surveys in different climatic seasons.

Sea Water. Environmental monitoring in the Contract Areas of the Company allowed identifying the annual ranges of hydrochemical values, which fit into well-known notions about their long-term variability in the North Caspian Sea:

- Average salinity is in the range of 5,64-8,36%
- Higher values of pH relate to Kashagan and Oil field pipeline operation
- Good conditions for sea water saturation by oxygen have been observed at all sites and in all seasons
- Turbidity values are mainly determined by wind and surging dynamics, consequently, the average maximum values are recorded at shallow water stations
- Biogenic elements have shown high year-to-year variability and in some years a seasonal variability. This is mainly due to combination of such reasons as rapid natural dynamics of biogenic compounds. Detected exceedance of biogenic elements concentration is, as a rule, local and short-term.
- Relation of increased hydrocarbon levels with a certain period in all surveyed water areas is not expressed or expressed weakly, because contamination was mostly episodic, local in space and dispersed in time. There are no sufficient grounds to consider the identified minor contaminations as man-caused.
- Dynamics of metals content values indicates a trend in decrease of their concentrations in recent years under review. Generally, the sea water quality in Contract Area waters can be considered as satisfactory in terms of metals content.

Bottom Sediments. The most significant changes in bottom sediments at Kashagan took place in 2011. Later, an evident relative increase of the proportion of medium-coarse-grained sand fractions in the sediments was recorded alongside with noticeable decrease in the content of smaller granulometric fractions.

With completion of active construction works in the field (2010-2011) involving soil dumping during construction of artificial islands, proportion of fine sand in sediments decreased gradually. By spring 2013, it reached the values that had been observed here prior to development activities. Starting from spring 2013, the grain-size composition of sediments has been stabilized and the content of main fractions practically has not changed.

In general, the bottom sediments quality in the surveyed water areas of the North-East Caspian Sea can be considered as satisfactory in terms of metals and hydrocarbons content.

No chronical contamination by any of the surveyed substances and change of physical-mechanical properties as the result of fixed sources impact have been revealed.

Concentrations of metals in bottom sediments do not exceed the permissible levels (except for some samples taken in certain locations).

The range of variation in hydrocarbons content in bottom sediments is high. The concentration of hydrocarbons is stable. Hydrocarbons of pyrogenic and biogenic origin are dominating (the result of organisms' vital activity and degradation, hydrocarbons generating from decaying of marine plants and animal remains). Exceedance of critical thresholds or indicative values was quite rare.

Phytoplankton. 503 species of algae have been revealed in the composition of phytoplankton. The number of plankton algae species ranged from 103 to 313 throughout the years. The most frequent were the blue-green algae Anathece clathrata, Lyngbya limnetica, Merismopedia minima, Merismopedia punctata, diatoms Cyclotella choctawhatcheeana, Cyclotella meneghiniana, and green alga Binuclearia lauterbornii.

The average long-term abundance of phytoplankton was 900.8 million cells/m3 with biomass of 616 mg/m3. The basis of abundance was formed by the blue-green algae (Cyanobacteria), while the basis of biomass was formed by the diatoms (Bacillariophyta).

The trend in increase of quantitative variables has been identified in the period of 2006 - 2016. The main contribution into year-to year increase in phytoplankton abundance was made by blue-green, diatom and green algae, and the contribution to biomass values increase was made by diatoms.

During the period under review there was a change in the dominant species complex in terms of biomass. In 2006–2007 the dominating species were diatomic algae C.meneghiniana, Actinocyclus ehrenbergii, Coscinodiscus lacustris, green alga B.lauterbornii, and blue-green algae Gomphosphaeriaaponia, Gomphosphaeria lacustris. In 2008–2010, the dominance shifted to the diatomic alga Coscinodiscus jonesianus. Since 2015 the role of diatomic algae Diploneis ovalis, A.ehrenbergii, Hyalodiscus sphaerophorus has been increased in phytoplankton.

The structure of phytoplankton depended on a number of natural and anthropogenic factors. The sea level drop was favorable for the main algae species. Decrease in concentration of some contaminants in the water had a positive effect on blue-green algae and some green algae.

Zooplankton. 119 taxa have been revealed in the composition of zooplankton in the surveyed water area. The number of plankton invertebrate species ranged throughout the years from 36 to 79. The baseline species included rotifer Brachionus quadridentatus, copepod Halicyclops sarsi, Acartia tonsa, Calanipeda aquae-dulcis, larvae of acorn shells Cirripedia, and bivalve mollusk Bivalvia.

The average long-term abundance of zooplankton comprised of 25,941 specimens/m3, with biomass of 415,2 mg/m3. Copepods were dominating in terms of abundance. The basis of biomass was formed by jelly fish. The highest values of the zooplankton biomass were confined to Kalamkas and Kashagan water area, which explains the domination of large jelly-fish. From 2008 to 2016 the quantitative variables of holoplankton had increased while biomass of jelly fish had decreased.

The composition of dominating species included more often the copepods Acartia tonsa and Calanipeda aquae-dulcis, in some parts of the water area – rotifers Brachionus angularis, Brachionus quadridentatus, cladoceran Cornigerius maeoticus, cyclop Halicyclops sarsi. Jelly fish Blackfordia virginica and Moerisia maeotica dominated in terms of biomass.

According to the Shannon index values, zooplankton had a low diversity level. The highest diversity of the community was formed in summer due to the presence of small size species.

A non-linear year-to-year trend in reduction of zooplankton average individual weight had been observed in all seasons. Given higher quantitative variables of zooplankton, this can indicate an intensification of eutrophication processes alongside with the sea level drop.

The major part of external factors had no statistically significant impact on year-to-year and spatial dynamics of plankton invertebrates.

Macrozoobenthos. The composition of macrozoobenthos included 175 taxa. The main contribution to the community species richness was made by crustaceans represented by 100 species. From year to year the numbers of benthic vertebrate species have been ranging from 57 to 111. The average long-term values of macrozoobenthos abundance and biomass were 7,877 specimens/m2 and 29,334 mg/m2 accordingly. The worms were dominating in terms of abundance. The basis of benthic cenosis biomass was formed by mollusks. The dominating complex composition included worms Oligochaeta gen.sp., Hediste diversicolor, Manayunkia caspica, Hypaniola kowalewskii, crustaceans of Corophium, Stenocuma, Stenogammarus genera, and mollusks Abra ovata, Cerastoderma lamarcki, Didacna trigonoides, Hypanis angusticostata.

Starting from 2010, the abundance of domestic species D.trigonoides, H.angusticostata, M.caspica had reduced. The role of Mediterranean introduced species such as A.ovata, C.lamarcki, H.diversicolor in the community had increased.

From 2006 to 2016 the trend in reduction of macrozoobenthos average annual abundance had been observed alongside with irregular year-to-year changes in biomass values. The abundance of small domestic polychaetes species such as M.caspica, H.kowalewskii and oligochaetes had significantly decreased.

Year-to-year dynamics of macrozoobenthos abundance depended on changes of natural factors, mainly hydrological (change of the sea level) and hydrochemical (salinity) parameters. The impact of anthropogenic factors on macrozoobenthos structure was assessed as local.

Ichthyofauna. In total, 70 fish species and subspecies were found in the period of environmental monitoring surveys in 2006 – 2016.

Nectonic community of fish amounted to 44 species and subspecies of 9 orders and 10 families. Most fish species belonged to the cyprinoid family (14 species), goby family (10 species), herring family (7 species), and sturgeon family (5 species). The average annual fish abundance in the catches ranged from 476 specimens per effort up to 1,013 specimens per effort. The catches biomass for the same period varied from 54 kg per unit effort up to 171 kg per unit effort.

Caspian roach was encountered in the nectonic fish community at least at 92-100% of the monitoring stations. High frequency of bream occurrence ranged from 70 to 92%, with big-eyed shad and Agrakhana shad from 44 to 75%. Due to the sea level drop and increase in the water salinity at the offshore section of the North-East Caspian Sea, over the last 5-6 years, such fish species as catfish and pike had completely disappeared from the net catches.

Species composition of the benthic-pelagic fish community in the monitoring catches amounted to 53 fish species and subspecies of 7 orders and 9 families. Most fish species belonged to the goby family (29 species), cyprinoid family (11 species), and herring family (5 species). The average annual fish abundance in catches varied from 373 specimens/ha to 1,566 specimens/ha. The catches biomass for this period varied from 3.2 kg/ha to 8.2 kg/ha.

In the benthic-pelagic community, a relatively uniform distribution across the water area was observed with pelagic fish species — Black Sea sprat, Caspian roach, bream, and atherines. At the same time, atherines gradually capture new territories. By 2010, long-tailed goby, goad goby, Ilyin goby had reduced significantly their range, and currently, they have a low frequency of occurrence. Even monkey goby, an absolute dominant, reduces its occurrence.

Till 2013, the average number of fish species per one monitoring station had been steadily decreasing. Reduction of species richness can be an indicator of the impact of a number of unfavorable factors on the ichthyofauna of the North Caspian Sea, which needs a more detailed study.

Abundance of two most mass fish species of the sturgeon family, stellate sturgeon and Russian sturgeon, reached its predicted minimum in 2014 and 2015. Analysis of the sturgeon abundance dynamics in Kashagan East and Kalamkas waters showed a similar trend in decrease of the sturgeon abundance in both sites located at 120 km distance from each other. During the 11-year monitoring period, the same happened to the Russian sturgeon with decrease of proportion of both the largest and the smallest specimens. This can be the indication of increase in the elimination of sturgeon breeders, for example, as a result of overfishing or poaching, which in its turn, leads to deterioration in reproduction and a decrease in the population replenishment by fish youngsters. Thus, the operations at the fields are not a determining contributor into such a catastrophic decrease in the abundance of valuable sturgeon species. The main causes of adverse impact on population of the most ancient representatives of the ichthyofauna existed much before the commencement of the Caspian shelf development.

The core of the benthic-pelagic fish community is formed by 8 species: 4 pelagic species - Black Sea and Caspian Sea sprat, Caspian roach, Bream, Aterina, and 4 seabed species - monkey goby, goad goby, bighead goby, and long-tailed goby.

Dynamics of the Black Sea sprat abundance by years at all monitoring areas had an irregular nature and did not depend on a specific water area. Aterinas abundance was the highest during all years of surveys in Kashagan East and Kalamkas. There is trend in increase in the abundance of this fish species in all surveyed areas. The lowest abundance of bream was recorded at Kalamkas field for all years; the highest abundance was observed at Kashagan field; the highest abundance of bream was usually observed in the offshore section of the Oil field pipeline. Changes in the abundance of Caspian roach by years at Kashagan and Kalamkas fields were almost completely the same, in spite of 120 km distance between them. Since no major petroleum operations have been carried out at Kalamkas field, this clearly indicates that the long-term development of Kashagan East area had no impact on the Caspian roach and on the dynamics of its abundance.

Periods of increase in abundance of monkey goby can be related to the changes in turbidity and granulometric composition of soil as a result of construction works in Kashagan East area and along the Oil field pipeline route. The long-tailed goblin also prefers the water area of the Oil field pipeline. While goad goby and bighead goby, on the contrary, prefer biotopes with deep, pure, salt water. The largest abundance of these species was confined to Kalamkas field water area. Such a distribution of preferences for environmental niches and biotopes within the goby family can be considered as adaptation to weakening of interspecies competition and more effective development of the areas.

The Caspian seal. Aerial surveys and icebreakers surveys allowed making a number of the following conclusions.

— The abundance of the Caspian seal continues to decline. During the period 2005–2008, records of the pupping rate and the number of adult seals on ice were taken. The pupping rate was approximately 21,000 — 17,000 specimens (2005–2006), dropping sharply up to 6,000 — 7,000 (2007-2008). In 2005, the total number of females was estimated as 55,000 specimens with the total number of the Caspian seals approximately 110,000 specimens. In the period 2005–2008, the number of born pups decreased by 60%, and the number of adult seals in the rookeries on ice had decreased by 30%.

— Enhanced methods of statistics analysis have provided a higher estimate for reproduction of the Caspian seal population, however, it does not eliminate grounds for concerns about the status of the seal population and the well-being of this species. Moreover, the other significant reproduction decline in the Kazakhstan sector of the Caspian Sea, noted in 2012 (the year of the last aerial survey of seals) gives even stronger grounds to worry that the fertility of the population is determined by some biological factors, and that the long-term sustainability of the Caspian seal population can be low.

— Seasonal variability, and consequently, the unpredictable occurrence of the areas with puppies along the icebreaker route are related to the annual nature of ice formation, late January – early February. This is the main factor determining available grounds for females and suitable for pupping. The surveys have confirmed that the most vulnerable are mothers with pups, who can appear in the corridor of icebreakers movement.

Introduction of a seals tagging method (telemetry method) by NCOC N.V. is an example of application of new survey technologies allowing to identify a number of new significant aspects in the behavior of the Caspian seal.

Results of satellite telemetry surveys in 2008–2013, provide reliable confirmation that the habitat area of the Caspian seal covers the North Caspian Sea water body and the coastal waters of the Middle Caspian Sea.

When moving to the north, seals use the "migration corridor" from the border with Turkmenistan to the mouth of the Zhayik River (Ural) along the coast of Kazakhstan, extending from the shore to about 50-meter isobaths. The continuous use of this corridor for several consequent years confirms its importance for seal migrations. This fact should be taken into account when assessing a potential impact of any activities including navigation and petroleum operations.

Shallow water areas of the North-East Caspian Sea from the Komsomolets Bay to the delta of the Zhayik River used by seals for moving, feeding and resting are the sea locations for autumn habitat of the Caspian seals awaiting the formation of winter ice. Therefore, it is absolutely necessary to take into account the potential impact of any operational activity on seals in this area during the autumn period. The nature of autumn-winter migration is more complicated than it was previously assumed.

The cumulative data about movements of the Caspian seals received in different years with satellite telemetry can be used for a more detailed analysis of their behavior and determination of migration routes, involving the results of other surveys (aerial surveys, vessel observations, etc.).

Ornithofauna. The North-East Caspian Sea region is of utmost importance for millions of waterfowl and semiaquatic birds that come here from a significant part of the northern half of the Eurasian continent - from Scandinavia to the Siberian tundra zone.

Despite the ongoing water level drop in the Caspian Sea and the drying of large areas suitable for water birds, the North-East Caspian Sea continues to play a leading role in the well-being of nesting and migratory birds, which is confirmed by establishment of 5 IBA of international importance within its territory and their approval as the Wetlands of National Significance.

The whole territory of the North-East Caspian Sea, from the Volga River Delta to the Seals Islands and Mangyshlak Bay is a single ecosystem, responding to changes in conditions in this area by redistribution, namely, in Kazakhstan sector of the North-East Caspian Sea. Changes in the abundance of individual species have a fluctuating nature, and do not show any obvious trends in decrease.

Artificial offshore structures are an attractive place for both nesting species and seasonal migrants. This is particularly evident at Kashagan offshore facilities, where the number of recorded species is double higher than at other locations.

Gradual increase in nesting species at offshore facilities was noted. Thus, a little tern and Caspian tern began to nest in Kashagan area on Island DC10, and a great cormorant was observed on Kairan Island.

In addition to offshore facilities, over a hundred species of birds use vessels and other floating facilities for resting and feeding during their seasonal migration.

Observations at Kashagan facilities confirm that artificial islands do not play any significant role for migrants. The number of birds making an emergency stop on the artificial islands under the survey is minor, and even in case of non-routine situations, they cannot affect the abundance of any of the noted species.

No negative impact of NCOC N.V. activities on the abundance and distribution of nesting and migrating birds for the entire monitoring period was identified. All changes are fully explained by natural (sea level drop) and anthropogenic factors (fires, poaching, higher disturbance factor due to increased human activities).

Thus, the offshore petroleum operations of NCOC N.V. Company are conducted at the time of natural environmental changes (climate warming, sea level changes, etc.), and various anthropogenic activities in the region and related impact factors (entry of contaminants with rivers inflow, from coastal sources, etc.). Results of environmental monitoring carried out by the Company have not enabled to establish an evident relation between the changes in marine biota, sea water, bottom sediments properties and the operations at offshore fields.

In its activity, NCOC N.V. Company adheres to very strict environmental standards and norms, as well as to relevant effective environmental requirements at the national and international levels. Compliance with environmental protection measures will allow minimizing significantly the impact of construction works, operation of offshore facilities and oil transportation on all components of the marine environment.

Results of environmental monitoring carried out regularly in the Company's Contract Areas have a scientific and applied value that allow tracing of the marine environment state and biodiversity of the North-East Caspian Sea area under survey.

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ANNEX 1

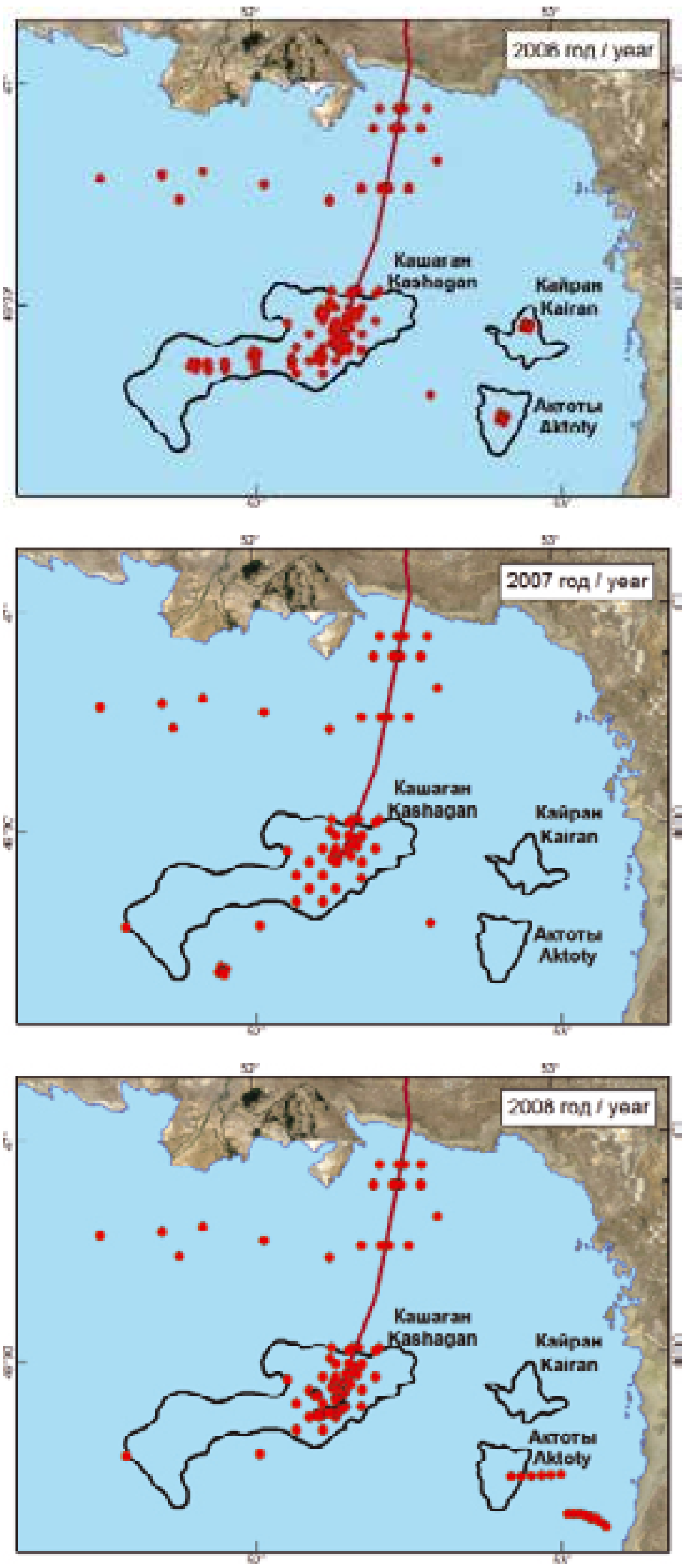

Fig. A1.1.

Kashagan, Kairan, Aktokte Fields. Environmental Monitoring Stations in 2006-2008

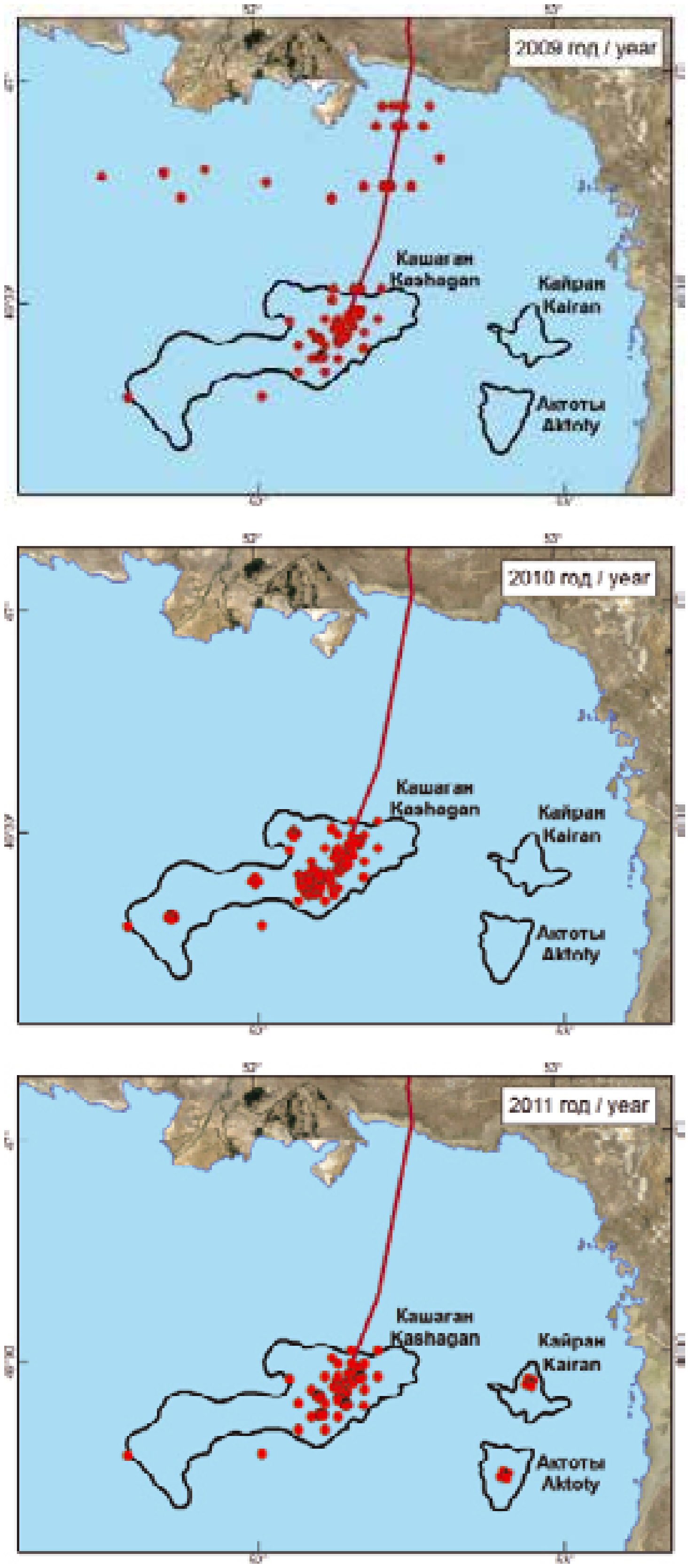

Fig. A1.2.

Kashagan, Kairan, Aktokte Fields. Environmental Monitoring Stations in 2009-2011

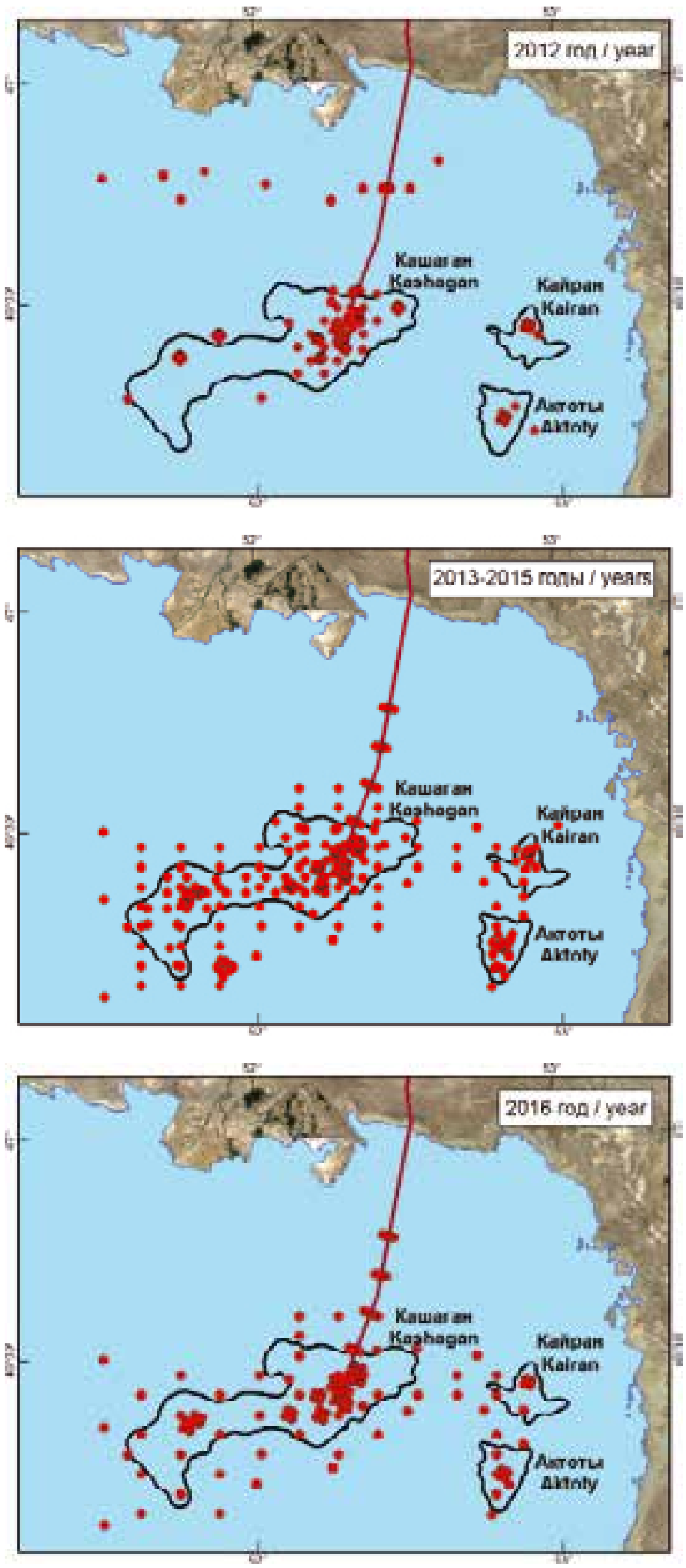

Fig. A1.3.

Kashagan, Kairan, Aktokte Fields. Environmental Monitoring Stations in 2012-2016

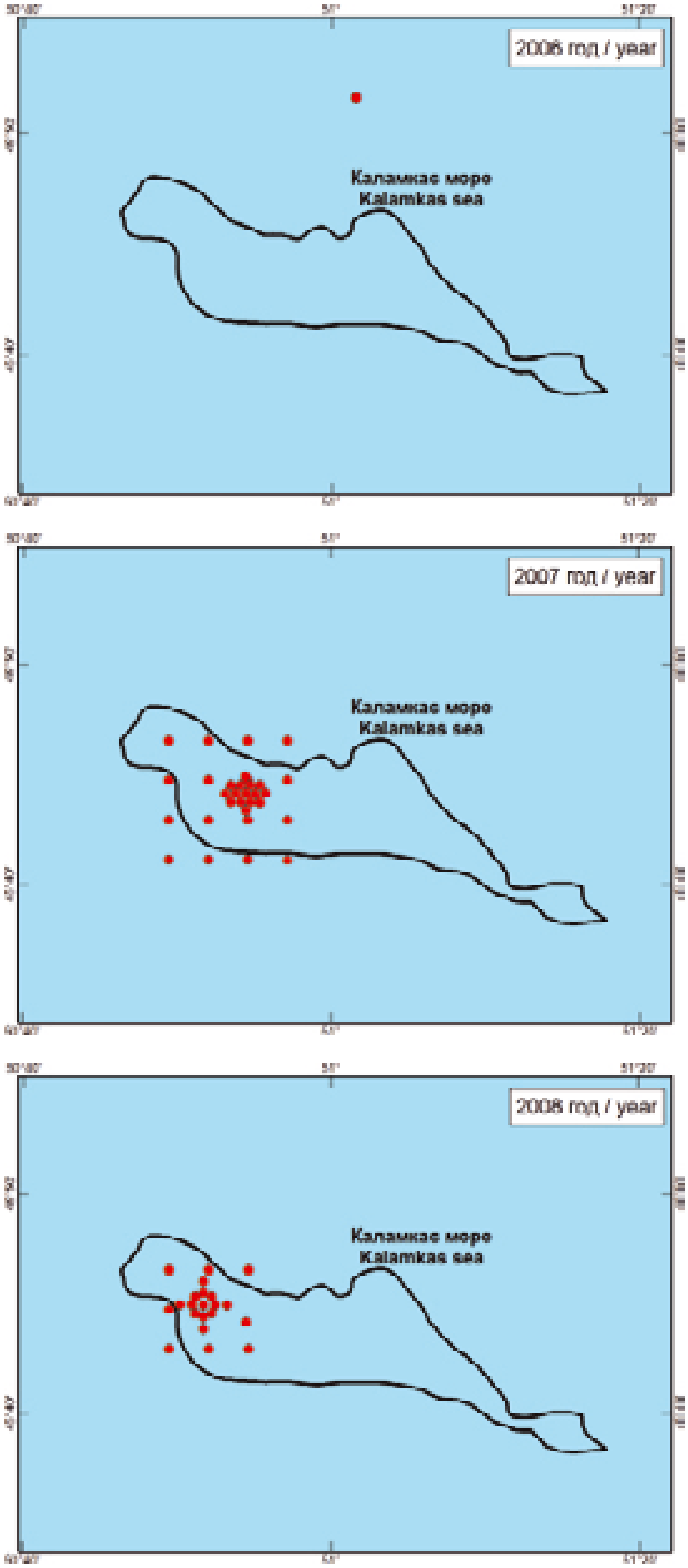

Fig. A1.4.

Kalamkas-Sea Field. Environmental Monitoring Stations in 2006-2008

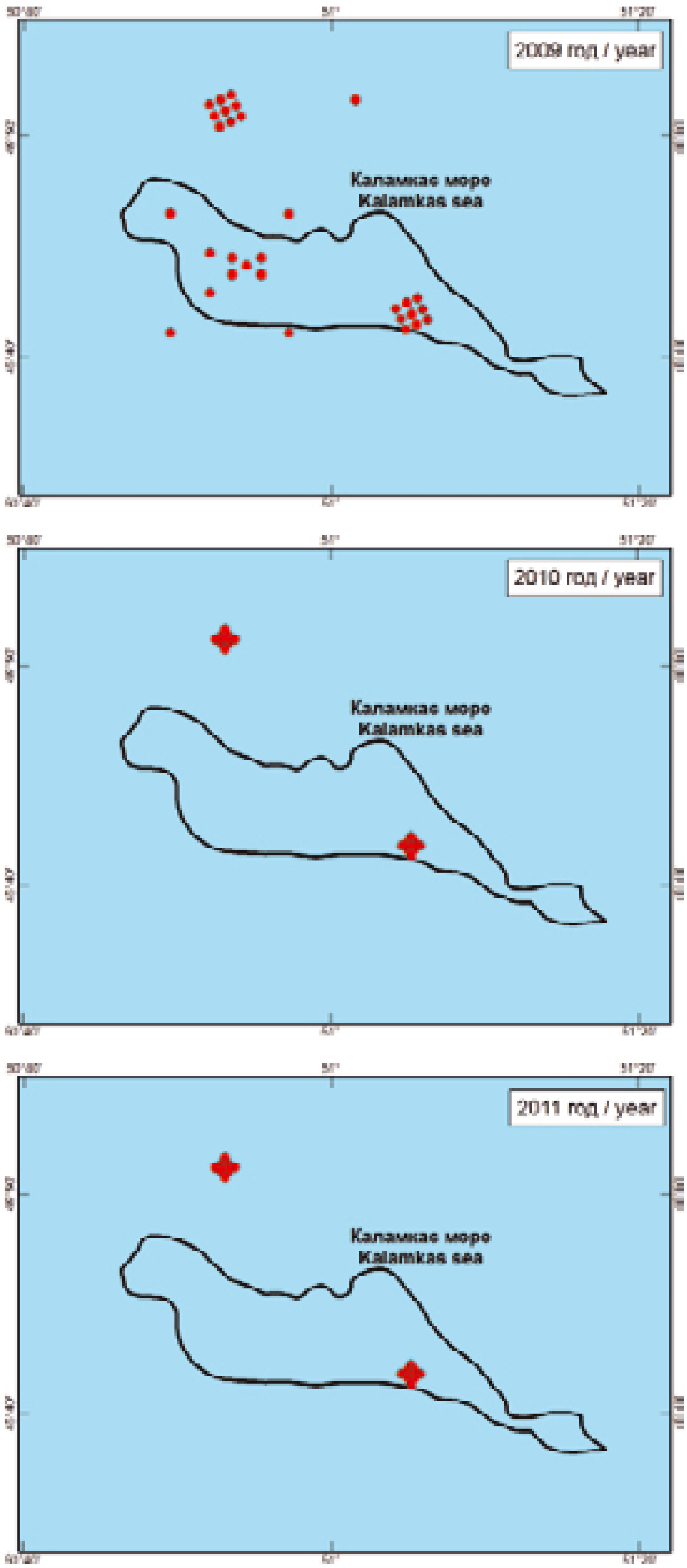

Fig. A1.5.

Kalamkas-Sea Field. Environmental Monitoring Stations in 2009-2011

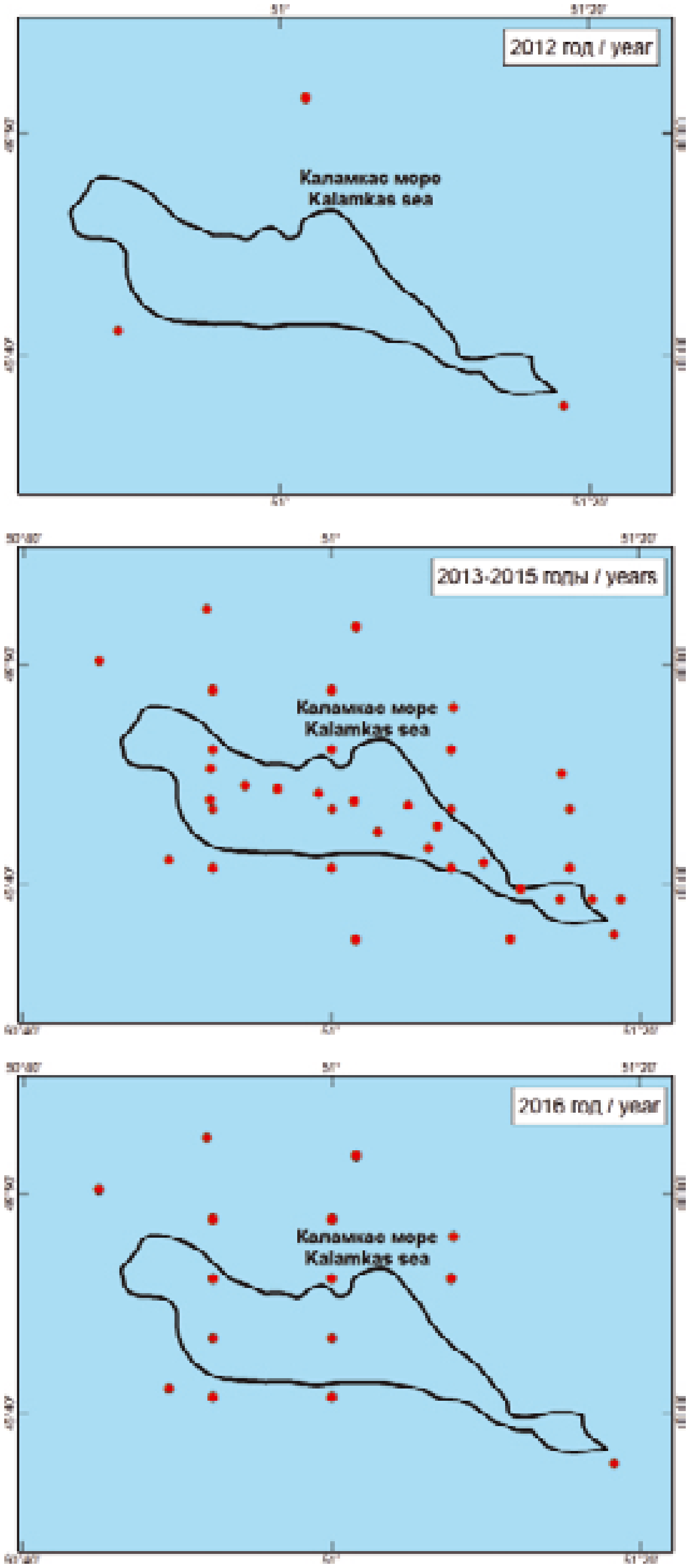

Fig. A1.6.

Kalamkas-Sea Field. Environmental Monitoring Stations in 2012-2016.

ANNEX 2

Below are the physical and chemical methods used to analyze the samples and the parameters of universal gas analyzer used to determine the concentrations of air pollutants from 2006 to 2016.

Table A.2-1 List of physical and chemical methods for analyzing air samples used in the 2006-2007 survey period

Parameters	Laboratory	Description of method	Detection limit	References
Sulphur dioxide	Scientific and Analytical Center LLP, Almaty	Photometric method with the use of photometer KFK-3-01	>0.05-1 mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.
Nitrogen dioxide	Scientific and Analytical Center LLP, Almaty	Photometric method with α-naphthylamine	>0.016-0.94 mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.
Carbon monoxide	Scientific and Analytical Center LLP, Almaty	Method of gas chromatography with the use of instrument Gazokhrom 3101	>0.1-30mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.
Hydrogen sulfide	Scientific and Analytical Center LLP, Almaty	Photocolorimetric method for formation of methylene blue	>0.003-0.075mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.
Hydrocarbons	Scientific and Analytical Center LLP, Almaty	Method of gas chromatography with use of instrument Gazokhrom 3101	>0.1-100mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.
Suspended matter	Scientific and Analytical Center LLP, Almaty	Gravimetric method	>0.007-16.7mg/m³	RD 52.04.186-89. Manual on control of air pollution, Gidrometeoizdat, 1991.

Table A.2-2 Main parameters of Universal Gas Analyzer "HANK-4AR"

Name of the instrument, type (brand)	Description of parameters	Basic metrological characteristics (range of measured concentrations)
Universal Gas Analyzer HANK-4AR	Concentrations:	NO from 0.03 mg/m³ to 100 mg/m³. NO_2 from 0.02 mg/m³to 40 mg/m³.
	Universal Gas Analyzer	H_2S from 0.004 mg/m³to 200 mg/m³.
	HANK-4AR	SO_2 from 0.025 mg/m³to 200 mg/m³.
	Sulfur dioxide (SO_2)	CO from 1.5 mg/m³ to 400 mg/m³.
	Carbon oxides (CO)	C_{12}-C_{19} from 0.5 mg/m³to 2000 mg/m³.
	Petroleum hydrocarbons (C_{12}-C_{19})	C_1-C_5 from 25 mg/m³to 35000 mg/m³.
	Hydrocarbons (methane) (C_1-C_5)	

Table A.2-3 Basic methods for determining air pollutants in 2015-2016

Pollutant	Description of method	References
Carbon oxide	Electrochemical	RD 52.04.186-89 Manual on control of air pollution, Gidrometeoizdat, 1991.
Hydrogen sulfide	Optron-spectrometric	MVI-4215-002-56591409-2009 Technique for measuring the mass concentration of harmful substances in the air with a gas analyzer HANK-4. Nature protection (MSOP). GOST 17.2.6.02-85. Atmosphere. Automatic gas analyzers for control of air pollution. General technical requirements.
Sulfur dioxide	Optron-spectrometric	MVI-4215-002-56591409-2009 Method for measuring the mass concentration of harmful substances in the air with gas analyzer HANK-4.
Nitrogen oxide	Optron-spectrometric	RD 52.04.186-89 Manual on control of air pollution, Gidrometeoizdat, 1991. GOST17.2.6.02-85 Nature protection (System of standards in nature protection). Atmosphere. Automatic gas analyzers for control of air. General technical requirements. MVI-4215-002-56591409-2009 Method for measuring the mass concentration of harmful substances in the air with gas analyzer HANK-4.
Nitrogen dioxide	Optron-spectrometric	RD 52.04.186-89 Manual on control of air pollution, Gidrometeoizdat, 1991. GOST17.2.6.02-85 Nature protection (System of standards in nature protection). Atmosphere. Automatic gas analyzers for control of air pollution. General technical requirements MVI-4215-002-56591409-2009 Method for measuring the mass concentration of harmful substances in the air with gas analyzer HANK-4.
Hydrocarbons $C_1 - C_5$	Thermocatalytic	RD 52.04.186-89 Manual on control of air pollution, Gidrometeoizdat, 1991. GOST17.2.6.02-85 Nature protection (System of standards in nature protection). Atmosphere. Automatic gas analyzers for controlling atmospheric pollution. General technical requirements
Hydrocarbons $C_{12} - C_{19}$	Thermocatalytic	RD 52.04.186-89 Manual on control of air pollution, Gidrometeoizdat, 1991. GOST17.2.6.02-85 Nature protection (System of standards in nature protection). Atmosphere. Automatic gas analyzers for control of air pollution. General technical requirements

Below is the analysis of the air pollutant concentration at Kashagan, Aktote, Kairan and Kalamkas fields at different level stations in the 2006-2016 survey period.

Table A.2-4 Analysis of air pollutants concentrations in Kashagan East in 2006-2016. (Level I monitoring stations)

		Concentration, mg/m³						
Pollutant	Value	2006	2007	2013	2014	2015	2016	*MPC$_{m.o.t.,}$. mg/m³
	Max	0.2367	0.037	0.049	<0.025	0.042	<0.025	
	Min	0.01	0.026	<0.025	<0.025	<0.025	<0.025	
Sulfur dioxide	**Average value**	**0.0502**	**0.031**	**0.037**	**<0.025**	**0.034**	**<0.025**	0.5
	Max	-	-	<0.03	<0.03	<0.03	<0.03	
	Min	-	-	<0.03	<0.03	<0.03	<0.03	
Nitrogen oxide	**Average value**	**-**	**-**	**<0.03**	**<0.03**	**<0.03**	**<0.03**	0.4

Pollutant	Value	2006	2007	2013	2014	2015	2016	*MPC$_{m.o.t.}$, mg/m³
		Concentration, mg/m³						
	Max	0.0277	0.086	0.054	<0.02	0.042	<0.02	
	Min	0.0012	0.006	<0.02	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.0087**	**0.0222**	**0.037**	**<0.02**	**0.031**	**<0.02**	0.2
	Max	0.0067	0.0009	<0.004	<0.004	<0.004	<0.004	
	Min	0.0009	0.0001	<0.004	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**0.0035**	**0.00034**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008
	Max	0.1228	0.7107	<25	<25	27.5	<25	
	Min	0.0121	0.057	<25	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**0.0325**	**0.33452**	**<25**	**<25**	**26.25**	**<25**	50.0
	Max	-	-	<0.5	<0.5	0.544	<0.5	
	Min	-	-	<0.5	<0.5	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**-**	**-**	**<0.5**	**<0.5**	**0.522**	**<0.5**	1.0
	Max	0.1079	0.225	2.11	2.67	3.2	<1.5	
	Min	0.1009	0.152	<1.5	<1.5	<1.5	<1.5	
Carbon oxide	**Average value**	**0.1038**	**0.1864**	**1.805**	**2.085**	**2.35**	**<1.5**	5.0
	Max	0.1235	0.107	-	-	-	-	
	Min	0.1029	0.091	-	-	-	-	
Suspended matter	**Average value**	**0.114**	**0.1016**	**-**	**-**	**-**	**-**	0.5

Note: **- Here and below are the values of MPCm.o.t. (Maximum permissible one-time concentration) in accordance with Annex 1 to the hygienic standards "Sanitary and epidemiological requirements for atmospheric air in urban and rural settlements" approved by Order No. 168 of the Minister of National Economy of the Republic of Kazakhstan dated February 28, 2015.*

Table A.2-5 Analysis of air pollutant concentrations in Kashagan East in 2012-2015. (Level II monitoring stations)

Pollutant	Value	2012	2013	2014	2015	MPC$_{m.o.t.}$, mg/m³
		Concentration, mg/m³				
	Max	<0.025	<0.025	<0.025	<0.025	
	Min	<0.025	<0.025	<0.025	<0.025	
Sulfur dioxide	**Average value**	**<0.025**	**<0.025**	**<0.025**	**<0.025**	0.5
	Max	<0.03	0.12	<0.03	<0.03	
	Min	<0.03	<0.03	<0.03	<0.03	
Nitrogen oxide	**Average value**	**<0.03**	**0.075**	**<0.03**	**<0.03**	0.4
	Max	<0.02	<0.02	<0.02	0.026	
	Min	<0.02	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**<0.02**	**<0.02**	**<0.02**	**0.023**	0.2
	Max	<0.004	<0.004	<0.004	<0.004	
	Min	<0.004	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008

Pollutant	Value	Concentration, mg/m³ 2012	2013	2014	2015	MPC m.o.t., mg/m³
	Max	-	<25	<25	<25	
	Min	-	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**-**	**<25**	**<25**	**<25**	50
	Max	-	0.554	<0.5	<0.5	
	Min	-	<0.5	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**-**	**0.527**	**<0.5**	**<0.5**	1
	Max	1.7	<1.5	3.32	3.74	
	Min	<1.5	<1.5	<1.5	<1.5	
Carbon oxide	**Average value**	**1.6**	**<1.5**	**2.41**	**2.62**	5

Table A.2-6 Analysis of air pollutant concentrations in Kashagan East in 2006-2016. (long-term observation stations / Level III monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2006	2007	2012	2013	2014	2015	2016	MPC m.o.t., mg/m³
	Max	0.3967	0.031	<0.025	0.029	<0.025	<0.025	<0.025	
	Min	0.0142	0.024	<0.025	<0.025	<0.025	<0.025	<0.025	
Sulfur dioxide	**Average value**	**0.1732**	**0.0274**	**<0.025**	**0.027**	**<0.025**	**<0.025**	**<0.025**	0.5
	Max	-	-	<0.03	0.367	<0.03	<0.03	<0.03	
	Min	-	-	<0.03	<0.03	<0.03	<0.03	<0.03	
Nitrogen oxide	**Average value**	**-**	**-**	**<0.03**	**0.199**	**<0.03**	**<0.03**	**<0.03**	0.4
	Max	0.0066	0.0262	<0.02	0.035	<0.02	0.032	<0.02	
	Min	0.0016	0.007	<0.02	<0.02	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.0043**	**0.0127**	**<0.02**	**0.028**	**<0.02**	**0.028**	**<0.02**	0.2
	Max	0.0061	0.0004	<0.004	<0.004	<0.004	<0.004	<0.004	
	Min	0.0007	0.0001	<0.004	<0.004	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**0.0023**	**0.00034**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008
	Max	0.0689	0.7107	-	<25	<25	<25	<25	
	Min	0.0055	0.0438	-	<25	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**0.0330**	**0.1723**	**-**	**<25**	**<25**	**<25**	**<25**	50.0
	Max	-	-	-	<0.5	<0.5	<0.5	<0.5	
	Min	-	-	-	<0.5	<0.5	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**-**	**-**	**-**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	1.0
	Max	0.1082	0.278	<1.5	1.77	3.19	4.5	<1.5	
	Min	0.0986	0.153	<1.5	<1.5	<1.5	<1.5	<1.5	
Carbon oxide	**Average value**	**0.1035**	**0.1855**	**<1.5**	**1.635**	**2.345**	**3.00**	**<1.5**	5.0
	Max	0.1235	0.107	-	-	-	-	-	
	Min	0.1029	0.091	-	-	-	-	-	
Suspended matter	**Average value**	**0.114**	**0.1016**	**-**	**-**	**-**	**-**	**-**	0.5

Table A.2-7 Analysis of air pollutant concentrations in Kashagan East in 2015-2016. (additional Level III monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2015	2016	MPC $_{m.o.t.,}$ mg/m³
	Max	<0.025	<0.025	
	Min	<0.025	<0.025	
Sulfur dioxide	**Average value**	**<0.025**	**<0.025**	0.5
	Max	<0.03	<0.03	
	Min	<0.03	<0.03	
Nitrogen oxide	**Average value**	**<0.03**	**<0.03**	0.4
	Max	0.023	<0.02	
	Min	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.021**	**<0.020**	0.2
	Max	<0.004	<0.004	
	Min	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**<0.004**	**<0.004**	0.008
	Max	<25	<25	
	Min	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**<25**	**<25**	50.0
	Max	<0.5	<0.5	
	Min	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**<0.5**	**<0.5**	1.0
	Max	2.33	<1.5	
	Min	<1.5	<1.5	
Carbon oxide	**Average value**	**1.915**	**<1.5**	5.0

Table A.2-8 Analysis of air pollutant concentrations in Kashagan East in 2006-2008 (under flare observations)

Pollutant	Value	Concentration, mg/m³									MPC$_{m.o.t.}$, mg/m³
		2006					2007		2008		
		KEA - 01 (baseline)	KEA - 01	KEA- 03	KEA - 04	KE5 - 02	KEA - 07 (baseline)	KEA - 07	KEA - 05 (baseline)	KEA - 05	
	Max	0.0046	0.006	0.0004	0.055	0.0132	0.0018	0.0015	0.002	0.003	
	Min	0.0026	0.005	0.0004	0.0004	0.0008	0.0011	0.0004	0	0.001	
Sulfur dioxide	**Average value**	**0.0036**	**0.005**	**0.0004**	**0.015**	**0.004**	**0.0015**	**0.001**	**0.001**	**0.002**	0.5
	Max	not found	0.004	0.023	0.007	0.015	0.01	0.011	not found	0.003	
	Min	not found	0.001	0.005	0.002	0.003	0.005	0.005	not found	0.0015	
Nitrogen oxide	**Average value**	**not found**	**0.0023**	**0.011**	**0.004**	**0.0085**	**0.008**	**0.007**	**not found**	**0.0014**	0.4
	Max	0.002	0.015	0.043	0.01	0.029	0.027	0.028	0.015	0.022	
	Min	0.002	0.002	0.002	0.002	0.008	not found	0.002	0.009	0.000	
Nitrogen dioxide	**Average value**	**0.002**	**0.006**	**0.016**	**0.007**	**0.017**	**0.027**	**0.016**	**0.007**	**0.008**	0.2
	Max	0.0013	0.002	0.0018	0.0055	0.0006	0.0001	0.0006	0.0006	0.001	
	Min	0.0012	0.001	0.0004	0.0001	0.0001	0.0001	0.0003	0.0006	0.001	
Hydrogen sulfide	**Average value**	**0.0013**	**0.001**	**0.0010**	**0.0022**	**0.0004**	**0.0001**	**0.0004**	**0.0006**	**0.001**	0.008
	Max	-	-	-	-	-	not found*	0.1	0.6	1.8	
	Min	-	-	-	-	-	not found	0.1	0.4	0.8	
Hydrocarbons (by petrol)	**Average value**	**-**	**-**	**-**	**-**	**-**	**not found**	**0.1**	**0.525**	**1.183**	5.0
	Max	0.9	0.9	0.3	0.0055	0.0006	-	-	-	-	
	Min	0.3	0.5	0.1	0.0001	0.0001	-	-	-	-	
Total hydrocarbons	**Average value**	0.667	0.75	0.233	0.0022	0.0004	-	-	-	-	50.0
	Max	0.26	0.37	0.38	0.26	0.1	0.21	0.23	0.18	0.29	
	Min	0.25	0.3	0.18	0.1	0.1	0.16	0.2	0.14	0.18	
Carbon oxide	**Average value**	**0.253**	**0.343**	**0.24**	**0.194**	**0.1**	**0.185**	**0.208**	**0.16**	**0.238**	5.0
	Max	not found	not found	not found	not found	not found	not found	not found	not found	not found	
	Min	not found	not found	not found	not found	not found	not found	not found	not found	not found	
Soot	**Average value**	**not found**	**not found**	**not found**	**not found**	**not found**	**not found**	**not found**	**not found**	**not found**	0.15

Table A.2-9 Analysis of air pollutant concentrations during well testing in Kashagan West

Pollutant	Value	Concentration, mg/m³ 2007 KW-2 (baseline)	KW-2	$MPC_{m.o.t.}$, mg/m³
	Max	0.002	0.005	
	Min	0.0007	0.0003	
Sulfur dioxide	**Average value.**	**0.001**	**0.0016**	0.5
	Max	0.002	not found	
	Min	0.002	not found	
Nitrogen oxide	**Average value**	**0.002**	**not found**	0.4
	Max	0.01	0.019	
	Min	0.003	0.003	
Nitrogen dioxide	**Average value**	**0.007**	**0.008**	0.2
	Max	0.0007	0.002	
	Min	0.0001	0.0003	
Hydrogen sulfide	**Average value**	**0.0004**	**0.001**	0.008
	Max	0.2	2.5	
	Min	0.1	0.1	
Hydrocarbons (by petrol)	**Average value**	**0.175**	**0.475**	5.0
	Max	0.21	0.3	
	Min	0.1	0.2	
Carbon oxide	**Average value**	**0.173**	**0.227**	5.0
	Max	not found	not found	
	Min	not found	not found	
Soot	**Average value**	**not found**	**not found**	0.15

Table A.2-10 Analysis of air pollutant concentrations in Kashagan West in 2015-2016. (Level I monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2015-2016	$MPC_{m.o.t.}$, mg/m³
	Max	<0.025	
	Min	<0.025	
Sulfur dioxide	**Average value**	**<0.025**	0.5
	Max	<0.03	
	Min	<0.03	
Nitrogen oxide	**Average value**	**<0.03**	0.4
	Max	<0.02	
	Min	<0.04	
Nitrogen dioxide	**Average value**	**<0.03**	0.2
	Max	<0.004	
	Min	<0.004	
Hydrogen sulfide	**Average value**	**<0.004**	0.008
	Max	<25	
	Min	<25	
Hydrocarbons C_1-C_5	**Average value**	**<25**	50.0
	Max	<0.5	
	Min	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**<0.5**	1.0
	Max	<1.5	
	Min	<1.5	
Carbon oxide	**Average value**	**<1.5**	5.0

Table A.2-11 Analysis of air pollutant concentrations at Aktote field in 2013-2016 (Level I monitoring stations)

Pollutant	Value	2013	2014	2015	2016	MPC $_{m.o.t.}$, mg/m³
		Concentration, mg/m³				
Sulfur dioxide	Max	<0.025	<0.025	<0.025	<0.025	
	Min	<0.025	<0.025	<0.025	<0.025	
	Average value	**<0.025**	**<0.025**	**<0.025**	**<0.025**	0.5
Nitrogen oxide	Max	<0.03	<0.03	<0.03	<0.03	
	Min	<0.03	<0.03	<0.03	<0.03	
	Average value	**<0.03**	**<0.03**	**<0.03**	**<0.03**	0.4
Nitrogen dioxide	Max	0.115	<0.02	<0.02	<0.02	
	Min	<0.02	<0.02	<0.02	<0.02	
	Average value	**0.068**	**<0.02**	**<0.02**	**<0.02**	0.2
Hydrogen sulfide	Max	<0.004	<0.004	<0.004	<0.004	
	Min	<0.004	<0.004	<0.004	<0.004	
	Average value	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008
Hydrocarbons C_1-C_5	Max	<25	<25	<25	<25	
	Min	<25	<25	<25	<25	
	Average value	**<25**	**<25**	**<25**	**<25**	50.0
Hydrocarbons C_{12}-C_{19}	Max	<0.5	<0.5	<0.5	<0.5	
	Min	<0.5	<0.5	<0.5	<0.5	
	Average value	**<0.5**	**<0.5**	**<0.5**	**<0.5**	1.0
Carbon oxide	Max	2.94	3.53	<1.5	<1.5	
	Min	<1.5	<1.5	<1.5	<1.5	
	Average value	**2.22**	**2.52**	**<1.5**	**<1.5**	5.0

Table A.2-12 Analysis of air pollutant concentrations at Aktote field in 2013-2015 (Level II monitoring stations)

Pollutant	Value	2013	2014	2015	MPC $_{m.o.t.}$, mg/m³
		Concentration, mg/m³			
Sulphur dioxide	Max	<0.025	<0.025	<0.025	
	Min	<0.025	<0.025	<0.025	
	Average value	**<0.025**	**<0.025**	**<0.025**	0.5
Nitric oxide	Max	0.066	<0.03	<0.03	
	Min	<0.03	<0.03	<0.03	
	Average value	**0.048**	**<0.03**	**<0.03**	0.4
Nitrogen dioxide	Max	<0.02	<0.02	<0.02	
	Min	<0.02	<0.02	<0.02	
	Average value	**<0.02**	**<0.02**	**<0.02**	0.2
Hydrogen sulfide	Max	<0.004	<0.004	<0.004	
	Min	<0.004	<0.004	<0.004	
	Average value	**<0.004**	**<0.004**	**<0.004**	0.008
Hydrocarbons C_1-C_5	Max	<25	<25	<25	
	Min	<25	<25	<25	
	Average value	**<25**	**<25**	**<25**	50.0
Hydrocarbons C_{12}-C_{19}	Max	<0.5	<0.5	0.519	
	Min	<0.5	<0.5	<0.5	
	Average value	**<0.5**	**<0.5**	**0.509**	1.0
Carbon monoxide	Max	1.53	1.99	3.01	
	Min	<1.5	<1.5	<1.5	
	Average value	**1.51**	**1.74**	**2.26**	5.0

Table A.2-13 Analysis of air pollutant concentrations during Kairan-2 well testing in 2007

Pollutant	Value	Concentration, mg/m³ 2007 Kairan-2 (baseline)	Кайран-2	MPC$_{m.o.t.}$, mg/m³
	Max	0.0003	0.011	
	Min	0.0003	0.001	
Sulfur dioxide	**Average value**	**0.0003**	**0.004**	0.5
	Max	0.005	0.005	
	Min	0.005	0.002	
Nitrogen oxide	**Average value**	**0.005**	**0.003**	0.4
	Max	0.013	0.003	
	Min	0.003	0.003	
Nitrogen dioxide	**Average value**	**0.008**	**0.003**	0.2
	Max	0.001	0.003	
	Min	0.0003	0.0001	
Hydrogen sulfide	**Average value**	**0.00065**	**0.001**	0.008
	Max	not found	not found	
	Min	not found	not found	
Total hydrocarbons (by petrol)	**Average value**	**not found**	**not found**	5.0
	Max	0.2	0.2	
	Min	0.1	0.1	
Carbon oxide	**Average value**	**0.125**	**0.1125**	5.0
	Max	not found	not found	
	Min	not found	not found	
Soot	**Average value**	**not found**	**not found**	0.15

Table A.2-14 Analysis of air pollutant concentrations at Kairan field in 2013-2016 (Level I monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2013	2014	2015	2016	MPC$_{m.o.t.}$, mg/m³
	Max	<0.025	<0.025	<0.025	<0.025	
	Min	<0.025	<0.025	<0.025	<0.025	
Sulphur dioxide	**Average value**	**<0.025**	**<0.025**	**<0.025**	**<0.025**	0.5
	Max	<0.03	<0.03	<0.03	<0.03	
	Min	<0.03	<0.03	<0.03	<0.03	
Nitric oxide	**Average value**	**<0.03**	**<0.03**	**<0.03**	**<0.03**	0.4
	Max	0.022	<0.02	0.021	<0.02	
	Min	<0.02	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.021**	**<0.02**	**<0.0205**	**<0.02**	0.2
	Max	<0.004	<0.004	<0.004	<0.004	
	Min	<0.004	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008
	Max	<25	<25	26.0	<25	
	Min	<25	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**<25**	**<25**	**25.5**	**<25**	50.0
	Max	<0.5	<0.5	<0.5	<0.5	
	Min	<0.5	<0.5	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	1.0
	Max	<1.5	2.1	<1.5	<1.5	
	Min	<1.5	<1.5	<1.5	<1.5	
Carbon monoxide	**Average value**	**<1.5**	**1.8**	**<1.5**	**<1.5**	5.0

Table A.2-15 Analysis of air pollutant concentrations at Kairan field in 2013-2015 (Level II monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2013	2014	2015	MPC m.o.t., mg/m³
	Max	<0.025	<0.025	<0.025	
	Min	<0.025	<0.025	<0.025	
Sulfur dioxide	**Average value**	**<0.025**	**<0.025**	**<0.025**	0.5
	Max	<0.03	<0.03	<0.03	
	Min	<0.03	<0.03	<0.03	
Nitrogen oxide	**Average value**	**<0.03**	**<0.03**	**<0.03**	0.4
	Max	0.022	<0.02	0.021	
	Min	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.021**	**<0.02**	**<0.0205**	0.2
	Max	<0.004	<0.004	<0.004	
	Min	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**<0.004**	**<0.004**	**<0.004**	0.008
	Max	<25	<25	25.4	
	Min	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**<25**	**<25**	**25.2**	50.0
	Max	<0.5	<0.5	0.544	
	Min	<0.5	<0.5	<0.5	
Hydrocarbons C_{12}-C_{19}	**Average value**	**<0.5**	**<0.5**	**0.522**	1.0
	Max	<1.5	1.8	<1.5	
	Min	<1.5	<1.5	<1.5	
Carbon oxide	**Average value**	**<1.5**	**1.65**	**<1.5**	5.0

Table A.2-16 Analysis of air pollutant concentrations at Kalamkas field in 2006-2016 (Level III monitoring stations)

Pollutant	Value	Concentration, mg/m³ 2006	2007	2013	2014	2015	2016	MPC m.o.t., mg/m³
	Max	0.1867	0.036	<0.025	<0.025	0.027	<0.025	
	Min	0.0125	0.0099	<0.025	<0.025	<0.025	<0.025	
Sulphur dioxide	**Average value**	**0.0996**	**0.0226**	**<0.025**	**<0.025**	**0.026**	**<0.025**	0.5
	Max	-	-	0.194	<0.03	<0.03	<0.03	
	Min	-	-	<0.03	<0.03	<0.03	<0.03	
Nitric oxide	**Average value**	**-**	**-**	**0.112**	**<0.03**	**<0.03**	**<0.03**	0.4
	Max	0.0048	0.0218	0.043	<0.02	0.038	<0.02	
	Min	0.0014	0.006	<0.02	<0.02	<0.02	<0.02	
Nitrogen dioxide	**Average value**	**0.0031**	**0.0116**	**0.034**	**<0.02**	**0.029**	**<0.02**	0.2
	Max	0.0018	0.0128	<0.004	<0.004	<0.004	<0.004	
	Min	0.0018	0.0004	<0.004	<0.004	<0.004	<0.004	
Hydrogen sulfide	**Average value**	**0.0018**	**0.0046**	**<0.004**	**<0.004**	**<0.004**	**<0.004**	0.008
	Max	0.038	0.2648	<25	<25	27.5	<25	
	Min	0.0224	0.0336	<25	<25	<25	<25	
Hydrocarbons C_1-C_5	**Average value**	**0.0302**	**0.1212**	**<25**	**<25**	**26.25**	**<25**	50.0

Pollutant	Value	2006	2007	2013	2014	2015	2016	MPC$_{m.o.t.}$, mg/m³
		Concentration, mg/m³						
Hydrocarbons C_{12}-C_{19}	Max	-	-	<0.5	<0.5	<0.5	<0.5	
	Min	-	-	<0.5	<0.5	<0.5	<0.5	
	Average value	**-**	**-**	**<0.5**	**<0.5**	**<0.5**	**<0.5**	1.0
Carbon monoxide	Max	0.1012	0.213	1.97	2.9	1.76	<1.5	
	Min	0.1009	0.0892	<1.5	<1.5	<1.5	<1.5	
	Average value	**0.1011**	**0.1454**	**1.735**	**2.20**	**1.63**	**<1.5**	5.0
Suspended matter	Max	0.1164	0.116	-	-	-	-	
	Min	0.0209	0.074	-	-	-	-	
	Average value	**0.0687**	**0.1002**	**-**	**-**	**-**	**-**	0.5

Table A.2-17 Volume of actual emissions of pollutants from fixed sources at Kashagan, Aktote and Kairan fields, in tons/year

№	Facility	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	Kashagan											
	Kashagan East											
1	A Island including well testing, flare, LQB	870	283	333	271	104	172	124	7	32	16	14
2	D Island including well testing, flare, LQB	-	-	178	89	156	326	-	-	-	381	260
3	Construction and installation of offshore facilities on A and D islands, etc.	870	283	333	271	104	172	124	7	32	16	14
4	Trunklines and infield pipelines (construction, installation)	-	-	178	89	156	326	-	-	-	381	260
	Kashagan West											
5	Kashagan West including well testing	311	289	165	-	-	-	-	-	-	-	-
	Kairan											
6	Kairan-2, including well testing	72	1031	-	-	-	-	-	-	-	-	-
	Kalamkas											
7	Kalamkas-4, including well testing	-	-	-	182	-	-	-	-	-	-	-

Note: * *hereinafter means that the work was not performed, there are no fixed sources of pollutant emissions.*

ANNEX 3

Table A.3-1 Methods and Methodology to determine sea water parameters

Years and seasons of monitoring

Seasons: 2006 (spring, autumn, summer); 2007 (autumn); 2008 (spring, autumn, spring); 2009 (autumn, spring); 2010 (autumn); 2011 (spring, autumn); 2012 (spring, autumn); 2013 (spring, summer, autumn); 2014 (spring, summer, autumn); 2015 (spring, summer, autumn); 2016 (spring, summer, autumn)

Pollutants	2006 spring – 2007 summer	2007 autumn – 2008 spring	2009 autumn	2009 spring	2010 autumn	2011 spring – 2012 autumn	2013 spring – autumn	2014 spring – 2015 summer	2015 autumn – 2016 autumn
Ammonium Nitrogen	Determination of ammonia by phenol-hypochlorite method according to Sedzhi-Solorzano, RD 118.02.3-90, CMEA "Unified methods for analysis of water quality" p.1, M., 1987	Photometric determining of ammonium nitrogen with Nessler reagent, GOST 4192-82	Spectrophotometry after distillation, GOST 4192-82		Photometry, RD 52.24.486-95	Photometry, RD 52.24.486-95, ST RK ISO 5664-2006	Photometry, GOST 26449.1-85	Photometry, ST RK ISO 5664-2006	Spectrophotometry, Methogology of Internal Measurements (MIM) No.101-08
Nitrite nitrogen	Determination of nitrites with α-naphthylamine and sulfanilic acid, RD 118.02.1-90, CMEA. "Unified methods for analysis of water quality" p.1, M., 1987	Photometric determining of nitrite nitrogen with a Griss reagent, GOST 4192-82	Spectrophotometry, GOST 26449.1-85		Photometry, RD 52.24.486-95		Photometry, GOST 26449.1-85	Spectrophotometry, ST RK 1963-2010	Spectrophotometry, MIM No.69-09
Nitrate nitrogen	Determination of nitrates by reduction to nitrites with zinc dust, RD 118.02.1-90, CMEA. "Unified methods for analysis of water quality" p.1, M., 1987	Photometric determining of nitrate nitrogen salicylate method, GOST 18826-73	Ion chromatography, GOST 26449.1-85		Photometry, GOST 18826-73	Photometry, ST RK ISO 7890-3-2006		Spectrometry, ST RK ISO 7890-3-2006	Spectrophotometry, MIM No.16-09
Total nitrogen	Determination of total nitrogen by persulfate burning, RD 118.02.1-90, CMEA. "Unified methods for analysis of water quality" p.1, M., 1987	Determination of total nitrogen by the summation method, GOST 4192-82, GOST 4192-82, GOST 18826-73	Spectrophotometry, GOST 26449.1-85	-				Calculation method	Spectrophotometry, MIM No.65-10

ы и сезоны проведения мониторинговых наблюдений

Pollutants	2006			2007	2008		2009		2010		2011		2012		2013			2014			2015			2016		
	spring	autumn	summer	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	autumn	spring	summer	autumn	spring	summer	autumn	spring	summer	autumn	spring	summer	autumn
Dissolved phosphorus, then total phosphorus from spring 2006 to spring 2009.	Photometric determination of phosphates, RD 52.24.43-87, CMEA "Unified methods for analysis of water quality" p.1, M., 1987			Photometric determining of phosphates, GOST 18309-72				Spectrophotometry, GOST 26449.1-85		Photometry, GOST 26449.1-85 p.14.2	Spectrophotometry, GOST 26449.1-85				Photometry, GOST 26449.1-85		Photometry, ST RK 2016-2010						Spectrophotometry, MIM No.25-10			
Heavy metals	Method for determination of cationic and anionic composition of aqueous extract. Mass spectrometry with inductively coupled plasma, GOST 26423-85, GOST 26426-85 Soil quality.			Method for determination of cationic and anionic composition of aqueous extract. Mass spectrometry with inductively coupled plasma, GOST 26423-85, GOST 26426-85 Soil quality.							Method for determination of cationic and anionic composition of aqueous extract. Mass spectrometry with inductively coupled plasma, ST RK-17294-2-2006												Atomic emission spectrometry with inductively coupled plasma, M 02-902-157-10 ICPE Registered in the RoK MIM Register No. KZ.07.00.01333-2011 of 14.06.2011.			
Phenols	Mass concentrations of phenols and volatile components in samples of natural and waste water, using the fluid analyzer "Fluorat-02", Method M 01-07-93. St.Petersburg, 1996.			Mass concentrations of phenols and volatile components in samples of natural and waste water with use a fluid analyzer "Flavobacteriumuorat-02", Method M 01-07-93. St.Petersburg, 1996.				Spectrophotometry after distillation, ISO 6439 Part B		Phenols in water determined using Fluorate, PNDF 14.1: 2: 4.182-02					Photometry, GOST 26449.1-85								Spectrophotometry, GOST 26449.1-85, p..25			
Total concentration of hydrocarbons	Method of gas chromatography, Appendix 4 to the publication of the British Ministry of Trade and Industry regarding conditions of oil discharge. Contaminated sludge formed as a result of offshore drilling operations. Methods for studying water and related material, 2004			Gas chromatography method, Internal Method for Determination of hydrocarbons in sea bottom sediments, water and biota using granulometry													Method of gas chromatography, ST RK, 2014-2010						Chromatography and mass-spectrometry, MIM LAE- 04/05 MIM Certificate of Attestation No.224.10.12.120/2006 reg. No.KZ.07.00.01113-2010 of 14.05.2010			

Table A.4-1 Composition of phytoplankton species and frequency of its occurrence in the North-East Caspian Sea

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cyanobacteria											
Anabaena aphanizomenoides	0.00	0.00	0.00	1.52	0.00	0.00	0.64	1.13	6.70	1.42	0.86
Anabaena bergii	8.05	16.39	0.00	3.79	0.00	0.00	0.64	1.98	5.36	1.70	6.44
Anabaena caspica	0.57	0.00	0.00	0.76	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Anabaena constricta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Anabaena constricta f.minima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Anabaena flos-aquae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	2.14	0.28	3.86
Anabaena kisselevii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Anabaena oscillarioides var. oscillarioides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Anabaena spiroides	0.57	6.56	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Anabaena subcylindrica	1.15	0.00	1.62	7.58	0.42	0.00	2.56	7.91	3.75	0.57	0.00
Anabaena variabilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.34	0.00	0.00
Anabaena volzii f.recta	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anabaenopsis cunningtonii	0.00	0.00	1.62	2.27	0.00	0.00	4.49	14.12	23.06	14.45	7.30
Anabaenopsis elenkinii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Anabaenopsis nadsonii	0.00	0.00	0.00	0.00	0.00	9.04	1.92	6.50	3.22	1.98	0.00
Anabaenopsis raciborskii	0.00	0.00	0.54	4.55	0.00	0.00	0.64	9.60	2.41	2.55	16.31
Anabaenopsis tanganyikae	0.00	0.00	0.00	0.00	0.00	0.00	5.77	0.56	3.49	0.00	2.15
Aphanizomenon flos-aquae	4.60	9.84	5.95	4.55	0.85	1.13	5.77	13.56	14.75	7.08	15.88
Aphanizomenon flos-aquae var. gracile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Aphanizomenon ovalisporum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.93	6.70	0.85	0.00
Anathece clathrata	12.07	16.39	24.86	50.76	39.83	73.45	59.62	53.67	54.16	39.66	63.09
Aphanothece elabens	0.00	0.00	0.00	0.76	0.00	0.00	0.64	0.28	5.09	12.46	27.90
Aphanothece stagnina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	3.68	7.73
Calothrix clavata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Coelosphaerium kuetzingianum	1.72	9.84	2.70	0.76	0.00	2.26	0.64	7.34	5.36	8.78	15.02
Coelosphaerium pusillum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61	1.42	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Dactylococcopsis acicularis	0.00	1.64	2.70	7.58	8.90	6.21	14.10	12.43	0.80	0.57	0.43
Dactylococcopsis irregularis	0.00	0.00	3.24	12.12	19.92	14.12	23.08	10.45	0.27	0.28	5.15
Dactylococcopsis raphidioides	0.00	0.00	0.00	3.03	0.85	0.00	3.21	0.00	1.34	0.00	0.43
Gloeocapsa cohaerens	4.02	0.00	2.16	1.52	0.00	2.82	2.56	4.80	1.34	0.57	6.44
Gloeocapsa crepidinum	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.85	0.54	0.85	0.00
Gloeocapsa limnetica	0.00	0.00	0.00	0.76	0.00	1.13	0.00	3.67	1.07	2.83	5.58
Gloeocapsa minima	2.30	11.48	0.54	25.00	22.88	37.29	53.85	47.18	43.97	40.79	37.34
Gloeocapsa minor	1.15	3.28	1.62	9.85	5.93	25.42	11.54	23.16	24.66	32.58	27.04
Gloeocapsa minor f.dispersa	0.00	0.00	0.00	0.00	1.27	0.00	0.00	0.00	0.00	0.28	0.00
Gloeocapsa minuta	0.00	1.64	7.03	54.55	49.15	71.19	57.05	52.26	37.27	19.26	3.86
Gloeocapsa turgida	5.17	8.20	1.62	0.76	0.42	6.78	5.13	2.54	0.27	0.57	6.87
Gomphosphaeria aponia	1.15	11.48	5.95	7.58	0.85	1.69	1.28	5.65	8.31	10.76	18.03
Gomphosphaeria aponina var. multiplex	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.11	4.02	0.00	0.00
Gomphosphaeria lacustris	14.37	1.64	1.62	1.52	0.42	0.00	0.64	6.50	12.87	5.67	11.16
Komvophoron constrictum	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Lyngbya aestuarii	0.57	0.00	0.00	0.00	0.00	0.56	7.69	0.28	0.00	0.00	0.00
Lyngbya confervoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Lyngbya contorta	0.00	1.64	8.65	40.15	11.44	25.99	48.08	50.00	61.13	73.94	67.81
Lyngbya kuetzingii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.43
Lyngbya lacustris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Lyngbya lagerheimii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.28	1.29
Lyngbya limnetica	13.79	24.59	24.86	50.00	33.90	79.66	58.97	76.55	94.64	74.22	5.58
Lyngbya martensiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Merismopedia elegans	0.00	0.00	0.00	0.00	0.00	0.00	1.28	3.39	0.00	0.00	3.00
Merismopedia glauca	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.00	1.34	2.83	7.30
Merismopedia minima	9.20	32.79	23.78	24.24	24.15	67.80	50.64	59.89	69.17	53.26	38.63
Merismopedia punctata	22.99	67.21	43.78	50.00	23.73	66.10	56.41	72.03	73.19	73.94	43.78
Merismopedia tenuissima	9.77	0.00	10.27	3.03	0.42	2.26	10.26	5.65	2.68	16.15	36.48
Microcystis aeruginosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	5.63	4.53	24.89
Microcystis aeruginosa f.flos-aquae	1.72	0.00	0.00	2.27	0.42	1.69	0.00	5.65	0.00	0.57	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Microcystis grevillei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	1.29
Microcystis ichthyoblade	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
Microcystis pulverea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.65	82.40
Microcystis pulverea f.delicatissima	0.00	0.00	0.00	0.00	2.54	0.00	2.56	16.10	4.02	6.23	0.00
Microcystis pulverea f.holsatica	0.00	0.00	0.00	2.27	0.00	0.00	6.41	3.11	1.61	0.28	0.00
Microcystis pulverea f.incerta	4.60	4.92	4.32	2.27	11.44	11.30	29.49	44.92	44.77	36.54	0.00
Microcystis pulverea f.planctonica	0.00	0.00	0.00	0.00	0.42	6.21	18.59	2.54	7.24	1.13	0.00
Microcystis pulverea f.pulverea	0.00	0.00	0.00	2.27	2.97	3.95	0.00	0.00	1.34	0.00	0.00
Microcystis salina	0.00	0.00	0.00	0.00	0.42	0.56	0.00	0.00	0.00	0.00	0.00
Microcystis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Nodularia spumigena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.00
Oscillatoria Agardii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29
Oscillatoria amphibia	0.57	34.43	22.70	25.76	13.56	38.42	60.26	68.93	77.75	28.90	3.43
Oscillatoria brevis	1.72	0.00	0.00	0.00	0.00	0.00	0.64	0.28	1.07	0.57	4.72
Oscillatoria chalybea	0.00	0.00	0.00	0.00	0.42	0.00	0.64	3.11	6.43	3.12	0.86
Oscillatoria chlorina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00
Oscillatoria fragilis	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Oscillatoria geminata	0.00	0.00	0.00	0.00	0.00	0.00	1.28	15.54	5.36	1.42	0.00
Oscillatoria limnetica	0.57	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	3.86
Oscillatoria limosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.39	8.04	3.12	0.00
Oscillatoria margaritifera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43
Oscillatoria mucicola	0.00	0.00	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	0.00
Oscillatoria planctonica	14.94	0.00	2.70	0.00	5.51	0.00	0.64	1.98	0.00	0.00	0.00
Oscillatoria princeps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Oscillatoria sp.	8.05	14.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oscillatoria tanganyikae var.caspica	0.00	0.00	0.00	0.00	0.42	0.00	8.97	3.11	0.80	0.28	0.00
Oscillatoria tenuis	1.72	0.00	0.00	0.00	0.00	0.00	0.00	2.26	7.24	1.42	1.72
Phormidium ambiquum	0.00	0.00	0.00	0.00	0.00	0.00	1.28	1.13	0.27	0.00	0.86
Phormidium angustissimum	9.20	0.00	0.54	0.00	0.85	0.00	6.41	5.65	0.00	25.21	85.41
Phormidium boryanum	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00
Phormidium sp.	34.48	22.95	8.11	15.15	0.42	23.16	34.62	38.42	63.54	41.36	3.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Phormidium tenue	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.00	1.88	3.40	58.37
Plectonema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.00	0.00
Pseudanabaena galeata	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Raphidiopsis mediterranea	0.00	0.00	0.00	0.00	0.00	0.00	1.92	0.28	0.27	0.85	0.00
Rhabdoderma lineare	0.00	0.00	0.00	0.00	0.00	0.56	4.49	5.93	3.22	0.00	0.00
Rhabdoderma lineare f.spirale	0.00	1.64	1.08	3.03	2.97	22.03	15.38	1.41	2.68	0.00	0.00
Spirulina laxa	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.54	10.20	28.76
Spirulina laxissima	0.00	3.28	3.78	8.33	8.05	31.07	42.31	40.68	26.01	26.63	75.97
Spirulina major	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.08	6.01
Spirulina subtillissina	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Spirulina tenuissima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Synechocystis salinus	0.00	0.00	2.16	1.52	3.81	15.25	8.97	6.78	1.34	0.00	0.00
Woronichinia naegeliana	0.00	0.00	0.00	0.00	0.00	0.00	3.21	0.00	0.00	0.00	0.00
Total of Cyanobacteria	**29**	**23**	**28**	**38**	**34**	**34**	**49**	**63**	**62**	**62**	**52**
Bacillariophyta											
Achnanthes affinis	0.00	0.00	0.00	0.00	0.42	3.39	0.64	3.67	0.54	0.28	3.86
Achnanthes brevipes	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.28	0.27	0.28	0.43
Achnanthes dispar	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.28	0.00	0.57	0.00
Achnanthes inflata	1.72	0.00	2.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.15
Achnanthes taeniata	0.00	0.00	0.00	0.00	0.00	0.00	1.28	1.98	2.95	3.40	0.00
Achnanthidium minutissimum	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00
Actinocyclus ehrenbergii	11.49	34.43	21.62	6.82	14.41	14.69	26.92	31.07	23.59	39.94	24.03
Actinocyclus paradoxus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Amphora coffeaeformis	18.39	1.64	4.32	0.76	0.85	7.91	11.54	15.25	28.95	57.51	28.76
Amphora commutata	0.00	1.64	0.00	2.27	1.69	0.00	1.28	1.69	3.22	9.63	0.86
Amphora holsatica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.41	3.49	0.85	0.00
Amphora ovalis	1.72	8.20	2.16	2.27	1.69	0.00	1.92	3.39	8.04	13.88	18.88
Amphora robusta	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.56	0.00	1.42	0.00
Amphora veneta	0.00	1.64	0.00	1.52	2.12	7.34	8.97	13.84	15.82	19.83	3.00
Aneumastus tuscula	2.30	8.20	11.89	0.00	0.42	3.39	2.56	5.37	13.14	15.30	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Anomoeoneis sphaerophora var. sculpta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Asterionella formosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	3.43
Bacillaria paradoxa	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Biddulphia sp.	0.00	0.00	0.00	2.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caloneis amphisbaena	0.00	0.00	3.24	0.00	2.12	0.00	1.92	2.82	5.36	7.93	1.72
Caloneis formosa	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.28	0.00	0.00	0.00
Caloneis formosa var.holmiensis f.attenuata	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Caloneis permagna	0.00	0.00	0.00	0.00	0.00	1.13	0.64	0.00	0.00	0.28	0.00
Campylodiscus araliensis	0.00	0.00	0.00	0.00	0.42	0.00	0.00	5.37	5.63	7.93	15.45
Campylodiscus clypeus	14.94	16.39	8.11	6.06	7.20	15.82	10.90	14.41	13.67	12.46	9.87
Campylodiscus clypeus var.bicostata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54	4.02	0.28	0.00
Campylodiscus daemelianus	0.00	0.00	0.00	0.76	2.12	0.56	0.64	2.26	0.54	0.57	9.44
Campylodiscus echeneis	2.87	0.00	0.00	0.76	0.42	0.00	1.92	1.69	0.27	0.00	0.00
Campylodiscus punctatus	0.00	0.00	0.00	0.00	0.00	0.00	2.56	0.00	0.00	0.00	0.00
Chaetoceros affinis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Chaetoceros convolutus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Chaetoceros diversicurvatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.54	0.28	0.43
Chaetoceros gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	0.00
Chaetoceros minutissimus	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	8.15
Chaetoceros mirabilis	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Chaetoceros muelleri	0.57	0.00	0.00	0.00	1.69	0.00	1.92	3.39	1.07	0.28	5.58
Chaetoceros paulsenii	0.00	0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.27	0.28	0.00
Chaetoceros rigidus	0.00	0.00	0.00	4.55	0.00	0.00	0.64	10.17	8.58	9.35	0.43
Chaetoceros seiracanthus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Chaetoceros simplex	0.00	0.00	0.00	0.00	0.42	1.69	1.28	0.56	2.41	0.28	9.44
Chaetoceros socialis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.28	0.27	0.28	0.00
Chaetoceros subtilis	0.00	0.00	1.62	2.27	0.42	1.13	0.64	0.85	8.04	0.00	0.86
Chaetoceros subtilis var.abnormis f.simplex	0.00	0.00	0.00	0.00	2.54	0.00	2.56	0.28	8.85	0.00	0.00
Chaetoceros wighamii	14.94	3.28	11.35	1.52	3.81	2.26	1.28	7.63	5.63	7.65	0.86

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cocconeis pediculus	2.87	8.20	2.70	5.30	1.27	2.26	0.64	1.69	3.22	6.52	11.16
Cocconeis placentula	1.15	0.00	8.11	1.52	5.51	2.82	9.62	3.95	2.68	8.50	9.44
Cocconeis scutellum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.85	0.43
Coscinodiscus gigas	0.00	0.00	0.00	0.76	0.85	0.56	1.92	7.06	7.51	4.53	0.43
Coscinodiscus granii	0.00	0.00	2.70	0.76	0.42	0.00	0.00	1.41	1.34	0.57	2.58
Coscinodiscus jonesianus	0.57	32.79	49.73	65.91	47.46	34.46	30.13	37.29	29.22	24.36	0.86
Coscinodiscus lacustris var.lacustris	10.92	3.28	0.54	2.27	6.78	0.00	0.00	1.98	0.00	2.83	7.73
Coscinodiscus perforatus	0.00	0.00	0.00	6.06	3.39	0.00	0.00	0.00	0.00	0.00	0.43
Coscinodiscus proximus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.58
Coscinodiscus radiatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Cyclotella choctawhatcheeana	7.47	40.98	22.70	32.58	23.73	77.97	72.44	73.45	91.42	94.62	82.83
Cyclotella comta	9.20	1.64	2.70	0.76	0.00	0.00	0.00	1.41	0.80	7.65	44.64
Cyclotella melosiroides	0.00	0.00	0.00	0.00	5.08	0.00	0.00	1.13	0.00	0.28	0.00
Cyclotella meneghiniana	62.07	55.74	43.78	13.64	60.59	66.67	70.51	61.02	56.30	36.83	35.62
Cylindrotheca closterium	8.62	22.95	26.49	16.67	13.14	20.34	32.69	49.72	52.01	65.44	38.20
Cylindrotheca gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.04	4.29	7.37	0.00
Cymatopleura elliptica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.85	0.43
Cymbella affinis	0.00	1.64	0.00	0.00	0.00	2.26	0.00	1.13	0.27	0.28	0.43
Cymbella cistula	0.00	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.43
Cymbella cuspidata	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Cymbella cymbiformis	0.00	0.00	0.00	0.76	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Cymbella lacustris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	1.07	0.00	0.00
Cymbella lanceolata	0.00	0.00	0.00	0.76	1.69	1.13	0.64	0.00	0.27	0.00	0.00
Cymbella lanceolata v.notata	0.00	0.00	0.00	0.00	0.85	0.00	0.00	1.13	1.88	0.57	0.00
Cymbella lata	0.00	0.00	0.00	0.00	0.42	0.00	0.00	2.26	0.00	0.00	0.86
Cymbella parva	1.72	4.92	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Cymbella prostrata	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.85	1.07	0.00	0.00
Cymbella pusilla	0.00	0.00	0.00	6.06	2.97	12.99	11.54	7.06	18.23	39.94	14.16
Cymbella tumida	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.54	0.00	0.43

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cymbella tumidula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	3.40	0.43
Cymbella turgida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Cymbella ventricosa	0.00	0.00	0.00	0.00	0.85	0.00	0.64	1.98	0.00	2.27	4.29
Dactyliosolen fragilissima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.43
Dactyliosolen fragilissimus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.27	0.00	0.00
Diatoma elongatum	0.00	0.00	0.00	3.03	0.00	3.95	1.28	1.13	9.92	12.18	4.29
Diatoma mesodon	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00
Diatoma vulgare	0.00	0.00	0.00	0.00	0.42	2.26	0.64	0.28	2.95	2.83	4.29
Diploneis dydyma	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.28	3.86
Diploneis interrupta	3.45	3.28	2.16	2.27	4.24	2.26	5.77	3.67	3.75	2.83	1.29
Diploneis ovalis	0.00	0.00	9.19	1.52	3.39	5.08	6.41	3.95	10.19	20.40	23.18
Diploneis Smithii	28.16	29.51	28.65	21.21	34.75	38.98	33.33	25.99	42.36	58.07	47.64
Entomoneis alata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	3.22	4.25	0.00
Entomoneis paludosa	3.45	4.92	4.32	0.00	2.54	3.95	1.92	3.11	6.43	15.58	18.88
Entomoneis paludosa var.subsalina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.80	0.28	0.00
Entomoneis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Epithemia sorex	0.57	0.00	2.70	0.00	0.85	2.82	1.28	0.28	3.75	2.55	1.29
Epithemia turgida	0.00	6.56	1.08	0.00	0.42	0.00	1.28	0.00	0.00	0.00	0.00
Fragilaria acus	0.57	0.00	2.70	2.27	1.27	2.26	0.64	0.85	1.61	1.70	3.00
Fragilaria amphicephaloides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.87
Fragilaria capucina var.capucina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	2.14	1.13	4.72
Fragilaria construens var.subsalina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	1.42	3.43
Fragilaria crotonensis var.crotonensis	0.00	11.48	0.00	0.00	0.00	0.00	0.00	0.28	1.61	0.28	3.00
Fragilaria virescens var.subsalina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95	1.13	0.00
Gomphonema angustatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.85	6.44
Gomphonema constrictum	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.28	0.27	0.00	0.00
Gomphonema constrictum var. capitatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Gomphonema lanceolatum var. capitatum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Gomphonema olivaceum	0.00	0.00	0.00	0.00	0.42	1.13	1.28	3.11	3.75	5.10	1.72

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Gomphonema parvulum	0.57	0.00	0.00	0.00	0.00	0.56	0.00	1.69	0.27	2.55	0.43
Gomphonema salinarum	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00
Gomphonema subsalinum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.93	1.34	0.28	0.00
Grammatophora marina	0.00	0.00	0.00	0.00	0.00	0.56	0.00	2.26	0.80	0.57	0.00
Grammatophora sp.	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Gyrosigma acuminatum	5.17	9.84	0.00	0.00	0.42	3.39	1.28	2.26	5.09	3.40	7.73
Gyrosigma attenuata	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	1.29
Gyrosigma balticum	1.15	3.28	3.78	0.76	0.00	1.13	1.28	0.56	0.27	0.57	0.00
Gyrosigma fasciola	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Gyrosigma scalproides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Gyrosigma Spencerii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Gyrosigma strigile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Hannaea arcus	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Hantzschia amphioxys	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Hantzschia virgata	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.56	0.27	0.57	0.00
Haslea spicula	0.00	0.00	0.00	2.27	8.90	5.65	8.33	22.03	35.39	17.85	14.16
Hippodonta costulata	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Hippodonta hungarica	0.57	0.00	5.95	0.76	0.85	0.56	0.00	0.28	0.00	0.57	1.29
Hyalodiscus sphaerophorus	0.57	0.00	0.00	1.52	2.54	9.60	4.49	15.25	18.23	18.13	36.91
Licmophora sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Mastogloia apiculata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	4.72
Mastogloia lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Mastogloia Smithii	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.43
Melosira granulata	1.72	19.67	4.32	0.00	0.00	0.00	0.00	0.28	0.27	0.00	2.15
Melosira granulata var.angustissima	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Melosira moniliformis	0.00	0.00	0.54	0.00	0.00	0.00	0.64	0.00	0.27	0.00	0.00
Melosira varians	0.00	0.00	0.00	0.00	0.42	3.95	1.92	0.56	8.58	0.28	0.43
Navicula bacillum	4.02	9.84	0.54	0.00	0.00	0.00	0.00	1.13	0.54	0.28	3.86
Navicula brasiliensis	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.28	0.00
Navicula cincta	13.79	8.20	7.57	2.27	5.08	3.95	7.69	0.56	4.29	5.38	10.30
Navicula costulata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Navicula cryptocephala	28.16	21.31	28.11	5.30	7.63	3.39	6.41	34.46	38.34	37.39	40.34
Navicula cuspidata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	1.88	4.53	1.29
Navicula cuspidata var.ambigua	0.00	0.00	0.00	0.00	0.42	0.56	0.00	0.00	0.00	0.00	0.00
Navicula cuspidata var.elongata	0.57	0.00	1.62	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navicula dicephala	0.00	0.00	0.00	0.00	0.00	0.00	4.49	0.85	0.00	0.28	3.43
Navicula digitoradiata	0.57	0.00	0.00	0.00	0.00	0.00	0.00	1.13	1.07	13.88	0.00
Navicula gastrum	2.87	9.84	0.00	0.00	0.42	0.56	1.28	0.00	0.00	0.00	0.43
Navicula Gregaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.33	36.48
Navicula halophila	0.00	0.00	10.27	5.30	10.59	9.04	6.41	14.69	12.33	12.46	15.88
Navicula halophila var.subcapitata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.28	0.00
Navicula incerta	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.28	0.00
Navicula lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.42	0.43
Navicula lanceolata var.tenella	0.00	0.00	0.00	0.76	0.00	0.56	0.00	0.56	3.49	9.35	0.00
Navicula lanceolata var.tenuirostris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Navicula menisculus	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.56	0.80	0.57	6.01
Navicula minima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	18.45
Navicula mutica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Navicula oblonga	0.00	0.00	0.00	0.00	0.42	0.00	0.00	1.13	0.00	0.00	0.00
Navicula peregrina	0.00	0.00	1.62	2.27	0.00	4.52	3.85	5.65	4.29	1.42	3.00
Navicula platystoma	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Navicula pusilla	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.27	1.70	1.29
Navicula pusilla var.jacutica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Navicula radiosa	10.34	13.11	19.46	4.55	12.29	9.04	12.82	28.25	25.20	30.31	6.87
Navicula rhynchocephala	0.57	0.00	10.27	11.36	2.97	5.65	10.90	13.84	12.87	14.16	12.45
Navicula salinarum	0.00	0.00	0.00	23.48	23.31	51.41	41.03	57.34	68.90	66.01	8.15
Navicula subrhombica	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Navicula tripunctata	1.15	3.28	0.00	0.00	0.00	0.56	5.77	3.11	3.75	11.05	13.73
Navicula viridula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Nitzschia acicularis	9.20	42.62	25.95	17.42	13.98	14.69	16.03	23.16	28.15	27.76	58.37
Nitzschia acicularis var.closterioides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61	0.00	0.00
Nitzschia angularis	0.00	0.00	0.54	0.00	0.42	0.00	0.00	0.56	0.27	5.95	3.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Nitzschia angustata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.15
Nitzschia aquaea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.57	0.00
Nitzschia circuminata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00
Nitzschia communis	0.00	0.00	0.54	0.00	0.00	0.56	0.64	0.00	0.00	0.00	0.43
Nitzschia commutata	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.28	0.00
Nitzschia dissipata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	1.70	2.15
Nitzschia distans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.54	0.00	0.00
Nitzschia epithemoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Nitzschia filiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.55	0.00
Nitzschia frustulum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.54	0.00	0.00
Nitzschia frustulum var.subsalina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.00	0.00
Nitzschia gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86
Nitzschia hantzschiana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	2.27	8.58
Nitzschia holsatica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88	0.00	0.00
Nitzschia hybrida	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.86
Nitzschia incerta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.80	15.01	0.00
Nitzschia lanceolata	0.00	0.00	0.00	0.00	0.00	0.00	1.92	0.00	0.00	0.28	0.43
Nitzschia linearis	0.00	0.00	0.00	0.00	0.42	1.13	0.00	0.56	0.27	0.28	0.43
Nitzschia longissima	0.00	0.00	0.00	0.00	0.00	1.69	0.64	1.98	6.43	2.83	6.01
Nitzschia lorenziana	2.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00
Nitzschia macilenta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Nitzschia navicularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.85	0.00
Nitzschia obtusa	0.00	0.00	0.00	0.76	0.00	0.00	0.64	0.00	2.41	1.70	0.43
Nitzschia parvula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Nitzschia punctata var.coarctata	0.57	0.00	0.00	0.00	0.42	2.82	1.28	1.69	0.00	1.13	0.00
Nitzschia recta	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.85	0.86
Nitzschia reversa	1.15	11.48	1.08	3.79	1.69	13.56	3.85	13.28	0.00	13.31	39.48
Nitzschia scalpelliformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Nitzschia sigma	24.71	9.84	22.70	12.88	15.68	9.04	12.82	15.25	26.01	35.13	17.17
Nitzschia sigmoidea	4.02	13.11	0.00	0.00	1.69	1.13	1.92	1.41	0.27	0.00	3.00
Nitzschia tenuirostris	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Nitzschia tryblionella	0.00	0.00	2.70	1.52	4.66	0.56	8.97	6.21	17.43	24.08	30.90
Nitzschia tryblionella var.constricta	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.28	0.00
Nitzschia tryblionella var.obtusiuscula	0.00	0.00	0.00	0.76	0.00	0.00	0.00	3.67	0.27	0.00	0.00
Nitzschia vermicularis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	2.82	0.80	1.13	5.15
Nitzschia vitrea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.85	0.00
Nitzschia vitrea var.salinarum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00
Paraplaconeis placentula	0.57	3.28	0.54	1.52	0.42	0.56	5.13	1.41	3.22	3.68	1.29
Pinnularia cardinalis	0.00	0.00	0.00	0.00	0.00	1.69	0.00	4.80	1.61	3.12	0.00
Pinnularia distinguenda	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.98	1.34	1.13	0.00
Pinnularia elegans	0.00	0.00	0.00	0.00	0.00	0.00	0.64	1.98	1.07	1.42	0.00
Pinnularia interrupta	0.00	0.00	0.00	0.00	0.85	0.56	1.92	0.28	0.27	1.13	3.00
Pinnularia interrupta var.minutissima	1.72	0.00	0.54	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Pinnularia major	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.00	1.29
Pinnularia mesolepta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	2.58
Pinnularia microstauron	0.00	0.00	0.00	0.00	0.00	0.00	0.64	2.54	0.00	0.00	0.00
Pinnularia parva	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	1.07	0.00	0.00
Pinnularia stauroptera var. semicruciata	0.00	0.00	0.00	0.00	0.42	0.00	0.64	0.56	0.00	0.00	0.00
Pinnularia viridis	0.00	0.00	0.00	0.76	0.00	0.56	7.69	0.00	0.54	0.28	0.43
Pinnularia viridis v.intermedia	0.00	0.00	0.00	3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Placoneis placentula var.rostrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Plagiotropis lepidoptera	0.00	0.00	0.00	0.00	0.42	0.56	1.92	1.69	3.75	4.53	0.00
Pleurosigma delicatulum	0.00	0.00	2.70	0.76	0.00	1.13	1.92	0.00	1.88	0.00	0.00
Pleurosigma elongatum var. elongatum	0.00	0.00	1.08	3.03	2.97	8.47	1.92	6.21	2.95	7.37	0.00
Pleurosigma salinarum var.salinarum	0.00	0.00	0.00	3.03	6.36	9.04	13.46	11.02	10.19	21.53	9.44
Pleurosigma subsalsum	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Podosira parvula	15.52	21.31	20.00	31.06	29.66	48.02	35.90	37.85	43.43	36.26	2.58
Proschkinia longirostris	0.00	0.00	0.00	0.76	0.00	0.00	0.64	3.67	8.31	11.33	0.00
Pseudosolenia calcar-avis	5.75	0.00	4.32	3.03	10.17	1.69	8.97	20.06	14.75	6.52	5.15
Rhoicosphaenia abbreviata	8.05	3.28	3.78	1.52	0.42	3.95	3.85	1.98	3.49	3.68	4.29
Rhopalodia gibba	0.00	3.28	1.08	0.76	0.42	5.65	0.00	1.69	0.80	0.85	15.02

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rhopalodia musculus var.musculus	0.57	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Sceletonema costatum	3.45	3.28	4.86	0.00	0.00	0.00	1.28	0.85	2.95	1.42	0.00
Sceletonema subsalsum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.27	0.85	0.00
Sellaphora pupula	1.72	4.92	9.73	5.30	6.78	9.60	32.05	23.45	27.08	51.56	23.18
Stauroneis anceps	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.85	0.00	0.00	0.00
Staurophora salina	0.00	0.00	0.00	1.52	0.42	0.56	1.92	0.85	0.80	6.80	0.43
Stephanodiscus astraea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.27	0.00	0.00
Stephanodiscus binderanus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Stephanodiscus hantzschii	2.87	8.20	0.54	3.03	0.00	0.00	3.21	1.69	2.68	1.13	0.00
Surirella didyma	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.56	0.54	0.28	0.00
Surirella elegans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.27	0.28	0.00
Surirella librile	2.30	6.56	1.08	0.00	0.42	0.00	0.64	1.41	1.88	1.13	2.15
Surirella linearis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Surirella minuta	0.57	3.28	0.00	0.00	0.85	1.13	1.92	0.56	1.34	2.27	3.43
Surirella ovalis	0.00	0.00	0.00	0.00	0.42	1.69	1.28	1.69	2.95	9.35	8.58
Surirella peisonis	0.00	0.00	0.54	0.00	0.00	3.39	0.64	0.00	0.00	0.57	0.00
Surirella robusta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.43
Surirella robusta var.splendida	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.00	0.00	0.00	0.00
Surirella salina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.26	2.41	1.13	0.00
Surirella striatula	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synedra spectabilis	0.00	0.00	0.00	0.00	0.00	0.00	1.28	0.00	0.00	0.85	0.00
Synedra tabulata var.obtusa	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Synedra tabulata var.tabulata	0.00	0.00	1.08	3.79	0.00	3.95	1.28	2.26	1.34	7.08	0.00
Tabularia fasciculata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Thalassionema nitzschioides	0.00	0.00	0.00	0.00	1.69	0.56	1.28	9.04	32.98	36.54	0.00
Thalassiosira affinis var.affinis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00
Thalassiosira caspica	0.00	0.00	0.54	0.76	0.00	5.65	12.18	27.40	31.64	25.21	6.44
Thalassiosira hendeyi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.57	0.43
Thalassiosira hustedtii var.vana	0.00	0.00	0.00	0.00	0.42	0.56	3.85	9.04	9.38	5.10	0.00
Thalassiosira incerta	9.77	0.00	9.19	0.76	9.32	15.82	6.41	0.85	2.14	16.43	4.29
Thalassiosira subsalina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.97	1.98	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Thalassiosira variabilis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	2.26	7.24	0.28	1.29
Tryblionella acuminata	0.57	0.00	2.70	0.00	0.42	2.26	1.28	2.82	4.29	13.03	0.00
Tryblionella apiculata	0.00	0.00	0.00	0.00	2.12	0.56	0.64	1.69	0.54	2.27	6.87
Tryblionella circumsuta	0.00	3.28	0.00	0.76	0.00	0.00	1.28	1.13	0.27	1.42	3.86
Tryblionella debilis	8.05	6.56	5.41	3.03	0.00	0.00	3.21	7.91	13.40	25.78	6.01
Tryblionella hungarica	10.34	6.56	5.41	0.76	1.69	0.56	1.28	2.82	0.00	1.13	0.00
Tryblionella levidensis	0.00	0.00	0.00	6.06	0.85	4.52	12.82	7.34	17.96	13.88	1.29
Tryblionella punctata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.43
Ulnaria ulna	3.45	9.84	5.41	0.00	0.00	3.39	0.00	0.85	1.88	1.42	0.43
Total of Bacillariophyta	**61**	**49**	**66**	**74**	**99**	**99**	**111**	**168**	**151**	**169**	**133**
Miozoa											
Ceratium hirundinella	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.28	0.00
Diplopsalis acuta	0.57	3.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exuviaella ostenfeldii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Glenodinium behningii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.57	3.86
Glenodinium caspicum	0.00	1.64	7.57	6.82	5.51	8.47	12.18	26.55	24.66	26.91	8.58
Glenodinium lenticula	7.47	1.64	0.00	0.00	0.00	2.26	0.00	1.41	0.80	0.57	2.15
Glenodinium pilula	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.43
Glenodinium rotundum var. rotundum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Glenodinium variabile	6.32	0.00	0.00	0.00	0.42	1.69	0.64	2.54	1.88	3.97	0.00
Gonyaulax digitale	0.00	0.00	0.00	0.00	0.00	2.26	1.28	0.00	0.00	0.00	0.43
Gonyaulax spinifera	0.00	1.64	0.54	1.52	1.69	11.30	0.00	8.19	11.53	8.78	0.00
Gymnodinium lacustre	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.28	0.00
Gymnodinium variabile	14.86	13.11	1.08	8.33	7.63	24.29	21.15	27.12	39.41	11.61	0.86
Lingulodinium polyedrum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Peridiniopsis polonica	0.00	0.00	0.00	0.00	0.00	2.82	3.85	7.91	17.43	8.22	0.00
Prorocentrum cordatum	15.52	31.15	16.76	15.91	3.81	3.95	14.74	14.97	24.93	19.83	12.45
Prorocentrum lima	0.57	0.00	14.59	4.55	6.36	5.65	7.69	4.52	16.35	5.67	0.43
Prorocentrum micans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.34	0.00	0.00
Prorocentrum obtusum	0.00	1.64	1.08	0.76	1.27	1.13	7.05	14.69	10.46	4.82	1.72

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Prorocentrum proximum	0.00	0.00	0.00	0.00	0.00	1.69	0.64	0.56	2.41	2.83	4.72
Prorocentrum scutellum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.25	13.14	11.33	0.43
Protoperidinium achromaticum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	1.29
Scrippsiella subsalsa	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.54	1.13	4.72
Scrippsiella trochoidea	12.64	3.28	4.32	0.00	1.27	0.00	0.00	6.50	7.51	0.85	10.73
Sphaerodinium cinctum	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Total of Miozoa	**7**	**8**	**7**	**6**	**10**	**12**	**9**	**15**	**16**	**17**	**15**
Ochrophyta											
Dinobryon balticum	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mallomonas sp.	0.0	0.0	0.0	0.0	3.4	7.9	8.3	15.3	15.3	11.6	0.0
Total of Ochrophyta	**0**	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**
Chlorophyta											
Actinastrum hantzschii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.28	0.00
Acutodesmus acutiformis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Ankistrodesmus arcuatus	70.11	70.49	57.30	18.18	17.80	15.82	35.90	31.92	34.85	26.35	33.48
Ankistrodesmus densus var.densus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Ankistrodesmus falcatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.86
Ankistrodesmus spiralis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Binuclearia lauterbornii	44.25	50.82	45.41	36.36	24.15	67.80	50.00	79.66	90.88	76.49	66.09
Binuclearia lauterbornii var.crassa	4.02	1.64	1.62	6.82	2.97	32.77	12.18	0.00	0.00	0.00	0.00
Botryococcus braunii	0.00	0.00	1.08	3.03	2.12	1.13	0.64	6.21	3.22	2.83	0.00
Characium acuminatum	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Characium bulbosum	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00
Chlorella vulgaris	0.00	11.48	5.41	10.61	5.08	10.73	15.38	17.23	22.52	10.48	0.43
Chlorococcum botryoides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.29	0.57	0.00
Chlorococcum infusionum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	2.68	0.00	0.00
Chlorolobion braunii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Chlorolobion obtusum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Chodatella hungarica	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Closteriopsis longissima	0.57	0.00	0.00	8.33	4.24	0.56	1.92	0.00	0.00	0.00	0.00
Closteriopsis longissima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.28	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Coelastrum microporum	0.00	0.00	1.08	0.00	0.00	0.56	0.00	3.39	2.14	0.00	1.72
Coenochloris pyrenoidosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.85	0.00
Coenolamellus botryoides	0.00	0.00	0.00	0.76	0.85	1.13	0.64	1.41	1.07	0.00	0.00
Cosmarium granatum	0.00	0.00	0.00	0.00	0.00	0.56	0.64	0.85	0.80	0.57	0.43
Cosmarium meneghinii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.43
Crucigenia emarginata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00
Crucigenia fenestrata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	3.00
Crucigenia quadrata var.quadrata	1.72	6.56	0.54	0.00	0.00	0.00	0.00	0.85	0.80	0.57	0.00
Crucigenia tetrapedia	3.45	4.92	0.00	0.00	0.00	0.00	0.00	0.28	4.56	2.55	7.30
Dictyochlorella globosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Dictyochlorella reniformis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.85	0.00	0.00	0.00
Dictyosphaerium ehrenbergianum	0.00	0.00	0.00	3.03	0.00	1.13	1.28	5.08	4.02	2.83	0.00
Dispora crucigenioides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Eremosphaera gigas	0.00	0.00	0.00	0.00	0.00	0.56	0.64	0.28	0.00	0.00	0.00
Glochiococcus aciculiferus	0.00	0.00	0.00	3.03	0.85	0.00	1.28	2.26	2.95	0.00	0.00
Golenkiniopsis parvula	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.72
Goniochloris mutica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Hyaloraphidium contortum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	3.68	0.00
Hyaloraphidium contortum var. tenuissimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.63	0.54	0.00	0.00
Kirchneriella irregularis	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Kirchneriella lunaris	0.00	6.56	7.57	3.79	0.85	4.52	3.21	2.26	5.90	4.53	3.00
Koliella longiseta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Korschpalmella microscopica	0.00	0.00	0.00	0.00	0.42	0.00	0.00	2.26	0.00	0.00	0.00
Lagerheimia genevensis var. genevensis	0.00	0.00	0.00	0.76	0.00	1.13	3.85	0.00	0.00	0.28	0.00
Lagerheimia quadriseta	0.00	0.00	0.00	0.76	0.00	0.00	2.56	1.98	1.61	0.28	0.00
Lagerheimia subsalsa	0.00	0.00	0.00	2.27	0.42	7.34	1.92	5.93	1.61	0.00	0.43
Lemmermannia komarekii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Monactinus simplex	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00	0.00	0.28	0.00
Monoraphidium contortum	0.00	14.75	18.38	45.45	8.05	19.77	32.05	34.46	39.68	45.33	50.21
Monoraphidium convolutus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Monoraphidium griffithii	1.72	8.20	1.08	0.00	2.12	1.13	1.92	15.82	13.14	14.73	0.43
Monoraphidium minutum	0.00	0.00	5.95	8.33	1.69	9.04	8.97	10.73	6.70	5.95	2.58
Monoraphidium obtusum	0.00	0.00	0.00	0.00	0.00	1.13	2.56	0.56	0.00	0.85	0.00
Mougeotia sp.	0.00	0.00	0.54	3.03	0.00	0.00	0.00	10.73	12.87	0.00	9.87
Mucidosphaerium pulchellum	11.49	34.43	12.43	9.85	0.85	7.91	5.13	23.16	13.94	9.63	19.74
Myrmecia irregularis	0.00	0.00	0.00	0.00	0.85	0.00	1.92	7.63	5.63	2.27	0.00
Neglectella solitaria	5.17	8.20	1.62	3.79	0.42	2.26	3.21	14.69	7.51	8.50	0.86
Oocystis apiculata var.apiculata	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Oocystis borgei	1.15	8.20	0.00	0.76	0.00	4.52	6.41	9.89	14.21	9.07	6.44
Oocystis composita	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.29
Oocystis cosialis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.28	0.00
Oocystis lacustris	2.87	11.48	4.86	3.79	0.00	3.95	3.21	1.98	3.49	0.28	5.15
Oocystis parva	0.00	0.00	0.00	0.76	0.42	2.26	0.00	3.11	3.49	0.00	0.00
Oocystis pusilla	0.00	0.00	0.00	0.00	0.42	0.56	1.28	0.28	1.07	0.00	0.00
Oocystis rupestris var.rupestris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Oocystis sp.	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oocystis submarina	0.00	1.64	0.00	3.03	0.00	1.69	0.64	0.56	0.80	0.28	0.00
Palmella miniata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Pediastrum duplex	1.15	3.28	1.08	0.00	1.27	1.13	0.00	0.00	1.88	0.00	2.15
Pediastrum duplex f.setigera	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Pediastrum integrum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00
Pediastrum tetras var.tetraodon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Planctonema sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.74	49.87	10.48	0.00
Pseudodidymocystis lineata	0.00	0.00	0.00	0.00	0.42	0.00	0.64	0.00	0.00	0.00	0.00
Pseudodidymocystis planctonica	0.00	0.00	0.00	1.52	0.00	3.39	1.28	5.65	2.14	3.68	0.00
Pseudopediastrum boryanum	2.30	8.20	3.24	5.30	3.39	1.69	1.28	5.65	7.77	4.82	4.29
Radiococcus sp.	0.00	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Raphidocelis danubiana	0.00	0.00	0.00	0.00	0.00	0.00	0.64	1.13	0.00	0.00	0.00
Scenedesmus acuminatus var. biseriatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Scenedesmus apiculatus var. apiculatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Scenedesmus arcuatus	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.85	0.00	0.85	0.43
Scenedesmus caudato-aculeolatus	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scenedesmus quadricauda	4.60	26.23	14.05	15.15	2.54	6.78	7.05	14.41	26.27	16.15	18.03
Schroederia setigera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Staurastrum gracile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.86
Staurastrum paradoxum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Staurastrum polymorphum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
Stauridium tetras	2.30	0.00	0.00	0.76	0.00	0.00	0.00	0.00	1.34	0.00	0.00
Tetradesmus cumbricus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Tetradesmus lagerheimii	1.15	16.39	5.41	3.79	0.00	1.69	2.56	1.13	6.97	2.27	9.87
Tetradesmus obliquus	4.02	8.20	2.16	1.52	0.00	1.13	1.92	5.93	5.36	2.55	8.15
Tetraedron caudatum	0.00	0.00	1.08	0.00	0.00	0.00	0.00	1.41	0.00	1.70	0.86
Tetraedron minimum	0.00	8.20	1.08	3.79	0.42	0.00	3.21	4.52	12.33	9.35	18.45
Tetraedron minutissimum	0.00	0.00	0.00	0.00	0.00	0.56	0.64	6.78	2.95	0.85	1.72
Tetraedron triangulare	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	1.07	0.28	0.00
Tetrastrum staurogeniaeforme	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Treubaria schmidlei	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.28	0.00
Trochiscia aspera	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00	0.00	0.00
Trochiscia planctonica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00
Total of Chlorophyta	**18**	**20**	**22**	**31**	**29**	**37**	**35**	**58**	**52**	**46**	**34**
Euglenozoa											
Euglena Ehrenbergii	0.00	0.00	0.00	0.76	0.00	0.56	0.64	3.39	0.27	1.42	0.00
Euglena gracilis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Euglena vermicularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.85	0.00
Euglena viridis	0.00	0.00	0.00	0.76	0.85	4.52	4.49	9.04	8.85	18.70	27.90
Euglenaformis proxima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Euglenaria caudata	0.00	0.00	0.00	3.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eutreptia viridis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.95	3.75	0.00	0.00
Lepocinclis acus	5.17	14.75	4.86	0.00	0.42	0.00	0.64	1.13	9.12	1.98	11.16
Strombomonas acuminata var. verrucosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Trachelomonas caudata	2.87	9.84	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.43
Trachelomonas globularis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Trachelomonas hispida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Trachelomonas volvocina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.00	0.00
Total of Euglenozoa	**2**	**2**	**1**	**3**	**2**	**3**	**3**	**7**	**8**	**4**	**3**
Total	**117**	**102**	**125**	**152**	**175**	**186**	**208**	**312**	**290**	**299**	**237**

Table A.4-2 Long term dynamics of phytoplankton abundance (million cells/m^3) (average for spring and autumn) in the North-East Caspian Sea

	Cyanobacteria	Bacillariophyta	Miozoa	Ochrophyta	Chlorophyta	Euglenozoa	Total of
2006	182.25	15.70	30.61	0.00	1.15	0.17	229.89
2008	121.12	17.64	29.80	0.06	1.28	0.09	170.00
2009	208.83	10.97	29.21	0.00	0.85	0.10	249.97
2010	216.42	14.22	12.90	0.06	0.60	0.02	244.22
2011	607.96	37.21	137.57	0.15	1.74	0.11	784.73
2012	580.31	29.85	31.99	0.14	1.34	0.10	643.74
2013	1258.54	83.10	84.82	0.26	2.61	0.04	1429.36
2014	1188.54	111.04	134.20	0.23	4.80	0.22	1439.03
2015	1185.01	114.37	181.79	0.21	1.85	0.04	1483.27
2016	1779.30	105.08	84.84	0.00	1.63	0.94	1971.79

Table A.4-3 Long term dynamics of phytoplankton biomass (mg/m^3) (average for spring and autumn) in the North-East Caspian Sea

	Cyanobacteria	Bacillariophyta	Miozoa	Ochrophyta	Chlorophyta	Euglenozoa	Total of
2006	30.62	120.29	5.14	0.00	24.67	0.90	181.62
2008	5.03	525.29	12.95	0.03	11.55	0.26	555.10
2009	53.54	488.39	8.08	0.00	11.12	4.90	566.03
2010	15.68	406.64	7.38	1.85	6.58	0.10	438.22
2011	36.81	416.60	27.24	3.23	33.27	1.84	518.98
2012	108.14	423.08	19.74	2.16	10.56	0.82	564.51
2013	77.36	514.45	56.49	3.93	26.91	0.45	679.59
2014	26.19	643.83	70.44	3.52	34.65	1.27	779.91
2015	19.51	814.81	49.07	3.22	41.44	0.28	928.34
2016	74.39	713.52	17.42	0.00	39.39	5.06	849.77

ANNEX 5

Table A.5-1 Composition of zooplankton species and frequency of its occurrence

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Rotatoria											
Asplanchna brightwelli	1.15	0.00	0.00	0.00	0.00	0.56	0.62	1.42	3.49	0.00	0.43
Asplanchna girodi	0.57	0.00	0.00	0.00	1.27	3.39	0.00	0.00	0.00	0.00	0.00
Asplanchna henrietta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Asplanchna herricki	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.25	0.00
Asplanchna priodonta helvetica	52.30	70.49	39.46	39.39	15.25	14.12	18.01	24.36	40.48	15.52	10.78
Asplanchna sp.	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Bdelloida fam.gen.sp.	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
Bipalpus hudsonii	0.57	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.27	0.00	0.86
Brachionus angularis	5.17	14.75	5.41	3.03	0.00	3.39	18.63	5.95	13.67	16.28	28.02
Brachionus calyciflorus	4.02	14.75	4.32	2.27	0.85	0.56	7.45	1.42	4.56	0.00	0.86
Brachionus diversicornis	0.57	34.43	14.05	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.43
Brachionus plicatilis	29.89	16.39	10.81	35.61	12.29	26.55	47.20	55.81	45.31	64.63	62.07
Brachionus quadridentatus	57.47	59.02	33.51	90.91	33.90	39.55	75.78	77.05	71.85	65.39	74.57
Brachionus urceus	0.00	1.64	3.24	0.00	0.00	0.00	11.18	0.28	2.14	1.78	0.00
Collotheca sp.	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.27	0.00	0.00
Encentrum sp.	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.25	0.00
Epiphanes sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Euchlanis dilatata	0.00	0.00	0.54	0.00	0.00	0.00	0.00	1.42	0.00	0.00	0.00
Euchlanis sp.	0.00	1.64	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filinia aseta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Filinia longiseta	27.59	57.38	3.78	22.73	2.12	9.60	25.47	23.51	28.95	16.28	42.24
Hexarthra fennica	0.00	0.00	0.00	0.00	0.00	0.00	0.62	5.10	14.21	6.11	15.95
Hexarthra oxyuris	0.00	0.00	0.00	0.00	0.00	0.00	1.86	1.13	0.00	0.00	0.00
Hexarthra sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.59
Kellicottia longispina	0.00	1.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Keratella cochlearis	1.15	0.00	0.54	0.00	0.00	0.00	0.00	4.25	0.80	1.53	0.00
Keratella quadrata	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.51	0.00
Keratella tropica	29.89	65.57	23.24	47.73	1.27	6.21	23.60	26.35	38.61	18.07	47.84
Lecane (Monostyla) sp.	0.57	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Lecane (s.str.) luna	0.00	14.75	3.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Notholca acuminata	1.72	6.56	2.16	0.00	1.27	0.56	4.35	0.00	3.22	1.27	0.43
Notholca japonicus	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Notholca squamula	1.72	0.00	0.00	0.00	0.00	2.26	3.11	1.42	4.83	1.53	0.00
Notholca sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Notommata sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Paradicranophorus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Polyarthra dolichoptera	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Proales sp.	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Synchaeta cecilia	12.64	9.84	2.70	0.76	0.42	0.00	0.00	2.27	13.94	5.60	0.43
Synchaeta littoralis	0.00	0.00	0.00	0.76	0.00	0.00	1.24	0.28	2.14	0.00	0.86
Synchaeta neapolitana	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Synchaeta pectinata	0.00	0.00	1.08	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Synchaeta stylata	35.06	49.18	34.59	40.91	21.19	6.21	0.00	8.50	32.98	18.32	0.86
Synchaeta vorax	0.57	0.00	0.00	0.00	0.00	0.00	8.70	18.70	20.64	19.08	21.55
Synchaeta sp.	33.33	26.23	14.59	6.06	1.69	6.21	4.35	6.23	10.99	3.05	9.91
Testudinella patina	1.15	9.84	1.08	1.52	2.12	2.26	2.48	1.42	3.75	1.78	2.16
Trichocerca (Diurella) heterodactyla	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.88	0.51	0.00
Trichocerca (s.str.) caspica	13.79	18.03	16.22	6.06	6.78	5.08	9.94	6.23	10.46	2.29	0.00
Trichocerca (s.str.) pusilla	0.00	13.11	2.16	0.00	0.00	0.56	0.62	0.00	1.61	1.53	0.00
Total of Rotatoria	**24**	**19**	**21**	**15**	**16**	**20**	**19**	**21**	**32**	**23**	**20**
Cladocera											
Alona rectangula	1.15	0.00	1.08	2.27	0.00	0.00	0.62	3.68	2.41	1.27	1.29
Alona sp.	0.00	13.11	1.08	1.52	0.00	2.26	1.24	0.00	4.02	1.27	0.43
Bosmina (Bosmina) longirostris	0.57	32.79	0.00	0.00	0.00	1.13	1.86	4.53	4.83	0.51	3.45
Polyphemus exiguus	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Chydorus sphaericus	1.15	13.11	0.00	2.27	0.00	1.69	0.62	0.57	0.54	0.25	3.02
Daphnia (Daphnia) longispina	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.25	0.00
Diaphanosoma brachyurum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.41	0.00	0.00
Diaphanosoma sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Graptoleberis testudinaria	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
Macrothrix hirsuticornis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.00
Moina brachiata	5.75	4.92	0.00	1.52	0.00	0.56	0.00	0.00	0.54	0.00	0.00
Moina micrura	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.85	0.00	0.25	0.43
Moina rectirostris	0.00	0.00	1.62	0.00	0.00	0.00	0.00	0.28	2.68	0.25	0.00
Pleuroxus truncatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Cercopagis (Cercopagis) gracillima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00
Cercopagis (Cercopagis) pengoi	0.00	0.00	0.54	3.03	0.00	0.00	0.00	4.25	9.12	0.51	2.59
Cercopagis sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00
Cornigerius maeoticus hircus	10.34	8.20	10.81	16.67	5.08	0.56	10.56	6.80	20.38	2.80	3.02
Evadne anonyx	12.07	0.00	5.41	27.27	15.68	2.26	6.83	2.27	4.29	1.53	0.86
Evadne prolongata	0.00	0.00	0.00	3.79	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Pleopis polyphemoides	8.62	1.64	2.70	7.58	8.90	3.39	3.73	4.25	4.83	5.09	0.86
Polyphemus exiguus	2.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Podonevadne angusta	24.71	3.28	7.03	37.88	6.36	0.00	3.11	1.13	2.68	0.00	0.00
Podonevadne camptonyx	74.14	27.87	47.03	76.52	38.14	29.38	47.83	28.05	24.40	12.21	19.83
Podonevadne trigona	82.18	95.08	39.46	79.55	39.41	32.77	47.83	25.78	32.44	18.58	31.03
Total of Cladocera	**12**	**9**	**10**	**13**	**7**	**9**	**10**	**13**	**19**	**14**	**11**
Copepoda											
Megacyclops viridis	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Mesocyclops leuckarti	0.00	11.48	6.49	0.76	0.85	11.86	7.45	16.71	21.72	9.92	0.43
Thermocyclops taihokuensis	0.00	0.00	0.00	0.00	0.00	1.69	0.00	0.00	0.00	0.00	0.00
Thermocyclops sp.	0.57	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.43
Acanthocyclops sp.	0.00	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00	0.00
Cyclops sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.43
Diacyclops sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Eucyclops sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00
Paracyclops sp.	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.27	0.00	0.43
Cyclopoida gen.sp.	23.56	0.00	0.54	3.79	0.85	0.00	3.11	13.03	0.54	1.78	14.66
Halicyclops oblongus	0.57	0.00	0.00	0.00	0.00	1.69	2.48	2.27	0.27	0.51	0.00
Halicyclops sarsi	78.74	95.08	95.14	86.36	43.64	14.12	21.12	47.31	74.53	18.32	51.29
Halicyclops sp.	0.57	0.00	0.54	0.00	5.93	0.00	0.62	0.85	1.88	3.31	10.78
Acartia tonsa	72.41	55.74	78.38	83.33	70.34	97.18	100.00	97.17	97.59	98.47	99.14
Calanipeda aquae-dulcis	106.90	109.84	101.62	96.97	99.58	100.00	100.00	100.00	100.00	100.00	100.00
Calanoida gen.sp.	0.00	0.00	0.00	0.76	6.78	0.00	0.00	0.00	0.00	0.00	0.00
Eurytemora affinis	3.45	11.48	15.14	0.00	0.00	3.39	0.00	3.40	3.22	0.00	0.86
Heterocope caspia	32.18	47.54	38.92	28.79	5.08	16.38	4.97	9.92	22.25	6.36	12.93
Ergasilidae gen.sp.	0.57	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Paraergasilus rylovi	6.32	16.39	1.08	6.82	0.42	4.52	0.62	8.50	6.43	4.07	4.74
Dichelesthium oblongum	0.00	0.00	0.00	2.27	2.97	1.13	0.00	1.70	0.00	0.25	0.00
Cletocamptus confluens	0.57	3.28	0.54	2.27	1.69	0.00	0.00	0.00	0.00	0.00	0.00
Cletodes sp.	1.72	0.00	2.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ectinosoma abrau	3.45	26.23	22.70	15.15	11.86	9.04	19.88	29.18	39.68	21.63	12.93
Ectinosoma concinnum	5.75	0.00	2.16	4.55	2.97	4.52	3.11	0.85	0.80	3.56	2.16
Ectinosoma sp.	0.57	0.00	0.00	1.52	0.42	0.00	2.48	0.00	0.54	2.04	2.59
Harpacticoida gen.sp.	32.76	45.90	32.97	18.94	21.19	18.08	31.06	30.03	58.98	43.00	32.33
Laophonte mohammed	12.07	9.84	16.22	10.61	11.44	5.08	11.80	4.53	7.77	3.56	2.16
Limnocletodes behningi	1.72	6.56	2.70	3.79	25.85	12.99	18.63	17.85	16.62	10.69	6.03
Limnocletodes sp.	0.00	0.00	0.00	0.76	1.27	5.65	0.00	1.13	0.00	0.00	0.00
Nitocra lacustris	0.57	0.00	0.00	3.03	1.69	0.00	0.00	0.00	0.00	0.00	0.00
Nitocra sp.	0.57	0.00	0.54	0.00	0.42	1.13	1.24	0.28	0.00	0.00	0.00
Nitocra typica	1.15	8.20	4.32	3.79	10.17	5.08	8.70	2.27	1.61	3.31	9.05
Schizopera akatovae	0.57	0.00	0.54	0.00	1.27	0.00	2.48	0.00	0.00	0.51	0.43
Schizopera neglecta	0.57	0.00	5.95	2.27	1.69	0.00	0.00	0.85	0.27	0.00	15.09
Schizopera paradoxa	0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00
Schizopera sp.	3.45	0.00	3.24	2.27	1.27	0.00	3.73	1.98	2.14	0.00	2.16
Tisbe sp.	0.00	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00
Total of Copepoda	**26**	**13**	**21**	**23**	**25**	**20**	**20**	**24**	**21**	**18**	**22**
Others											

Name of taxon	Frequency of occurrence, %										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Cirripedia gen.sp.	91.38	91.80	95.68	99.24	95.76	93.22	80.75	83.85	82.31	79.13	89.66
Rhithropanopeus harrisii	1.15	0.00	0.00	2.27	0.00	7.91	3.11	13.60	12.60	13.49	12.93
Mnemiopsis leidyi	0.00	0.00	0.00	0.00	1.69	0.00	0.62	0.00	0.00	0.25	0.00
Blackfordia virginica	11.49	8.20	5.41	9.85	21.19	25.99	16.77	32.58	40.48	36.90	20.69
Moerisia maeotica	0.57	0.00	1.62	0.00	2.54	5.08	0.62	5.67	6.70	17.30	15.95
Moerisia pallasi	0.00	0.00	1.08	2.27	1.69	3.95	0.00	9.92	0.00	4.83	20.26
Bivalvia gen.sp.	17.24	0.00	69.73	65.91	55.93	55.37	82.61	77.90	79.62	84.22	86.64
Hediste diversicolor	0.57	0.00	1.08	10.61	56.36	47.46	37.89	49.29	35.66	56.74	63.79
Trematoda gen.sp.	0.00	0.00	2.70	14.39	6.36	20.34	4.97	24.65	27.08	14.25	4.31
Total of Others	**6**	**2**	**7**	**7**	**8**	**8**	**8**	**8**	**7**	**9**	**8**
Total of:	**68**	**43**	**59**	**58**	**56**	**57**	**57**	**66**	**79**	**64**	**61**

Table A.5-2 Long term dynamics of zooplankton abundance (average for spring and autumn) in the Caspian Sea

	Rotatoria	Cladocera	Copepoda	Jellyfish	Others	Total
2008	1730	484	10473	2	2661	15350
2009	6812	1159	9765	6	4153	21896
2010	818	1414	7645	4	4005	13886
2011	2439	110	23542	51	4830	30972
2012	8104	315	15436	20	2995	26870
2013	3532	973	26965	3	1482	32955
2014	6357	144	17689	35	4255	28479
2015	2693	135	12278	8	3484	18599
2016	5667	181	30255	9	8352	44465
Average	**4239**	**546**	**17117**	**15**	**4024**	**25941**

Table A.5-3 Dynamics of zooplankton biomass (average for spring and autumn) in the Caspian Sea

	Rotatoria	Cladocera	Copepoda	Jellyfish	Others	Total	Total (excluding Jellyfish)
2008	2.2	11.9	50.0	319.6	6.0	389.7	70.1
2009	11.5	48.0	58.6	191.0	17.7	326.8	135.7
2010	0.7	19.9	42.7	790.4	15.5	869.1	78.8
2011	4.0	3.4	133.8	344.6	17.0	502.7	158.1
2012	5.3	15.2	116.8	409.9	16.3	563.6	153.7
2013	3.2	26.9	105.5	31.9	9.8	177.3	145.4
2014	4.6	5.2	65.6	212.6	11.8	299.9	87.2
2015	2.0	3.8	87.4	133.6	11.3	238.1	104.5
2016	8.0	3.5	187.8	135.9	34.6	369.7	233.8
Average	**4.6**	**15.3**	**94.2**	**285.5**	**15.6**	**415.2**	**129.7**

Таблица П.6-1 Вито вой состав и частfroma встречаемости таксонов макрозообентоса северо-восточной части Каспийского моря в 2006-2016 гг.

	Frequency of occurrence, %											
Name of taxon	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
Porifera – Sponges												
Metschnikowia tuberculata	0.00	0.00	4.95	8.33	12.14	2.94	1.98	11.89	4.55	5.08	0.58	5.63
Total of taxa Porifera	0	0	1	1	1	1	1	1	1	1	1	1
Hydrozoa – Hydrozoans												
Blackfordia virginica	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Bougainvillia megas	8.31	29.37	23.51	29.76	20.41	17.65	12.46	10.40	17.20	9.29	3.22	13.67
Cordylophora caspia	11.82	0.00	1.98	2.78	0.00	0.80	1.70	0.26	0.09	1.89	0.88	1.47
Moerisia pallasi	6.71	0.00	0.25	5.16	2.58	4.55	3.12	2.19	1.87	1.72	1.46	2.36
Moerisia sp.	0.00	0.00	0.00	0.00	0.52	1.87	1.13	0.00	0.00	0.00	0.00	0.21
Hydrozoa gen.sp.	0.00	0.00	4.46	5.56	1.03	1.07	0.85	2.71	0.45	8.26	6.14	3.43
Total of taxa Hydrozoa	3	1	4	4	4	5	5	4	4	5	4	6
Vermes – Worms:												
Nemertini – Nemertines												
Nemertini gen.sp.	0.00	0.00	0.25	0.00	0.00	0.00	0.28	0.00	0.00	0.26	0.58	0.14
Total of taxa Nemertini	0	0	1	0	0	0	1	0	0	1	1	1
Plathelminthes – Flat worms												
Turbellaria gen.sp.	0.00	0.79	25.00	15.08	6.46	6.95	4.82	4.81	3.21	4.30	5.12	6.07
Total of taxa Plathelminthes	0	1	1	1	1	1	1	1	1	1	1	1
Nemathelminthes – Roundworms												
Nematoda gen.sp.	24.60	52.38	59.65	67.86	40.57	35.56	33.71	26.40	33.87	37.69	37.43	37.02
Total of taxa Nemathelminthes	1	1	1	1	1	1	1	1	1	1	1	1
Annelida – Annelids:												
Polychaeta – Polychaetes												
Fabricia sabella caspica	0.00	0.00	0.25	0.00	0.00	0.00	0.28	0.09	0.00	0.86	0.15	0.22
Manayunkia caspica	79.55	82.54	89.11	91.67	79.33	64.44	55.52	43.09	42.69	43.63	32.60	53.63
Hypania invalida	0.00	0.79	10.15	0.79	1.29	1.34	0.28	0.09	0.09	3.27	20.18	3.69
Hypaniola kowalewskii	95.21	96.03	94.06	96.03	82.17	52.94	54.39	72.99	82.09	82.70	85.38	79.89
Ampharetidae gen.sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	4.39	0.50
Hediste diversicolor	94.89	90.48	97.77	97.22	98.71	100.00	99.15	96.85	99.38	99.23	100.00	98.35
Total of taxa Polychaeta	3	4	5	4	4	4	5	5	4	6	6	6
Oligochaeta – Oligochaetes												

Name of taxon	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
												Frequency of occurrence, %
Oligochaeta gen.sp.	98.40	98.41	100.00	100.00	99.22	92.78	96.03	95.98	99.55	97.93	98.25	97.82
Total of taxa Oligochaeta	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Hirudinea – Leeches												
Archaeobdella esmonti	0.32	0.00	0.00	0.00	0.00	0.53	0.28	0.00	0.09	0.00	0.00	0.08
Caspiobdella caspica	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Caspiobdella tuberculata	0.00	0.00	1.49	0.79	0.78	0.27	0.00	0.00	0.00	0.09	0.00	0.21
Caspiobdella sp.	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Piscicola caspica	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.09
Piscicola sp.	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Hirudinea gen.sp.	0.00	0.00	0.25	2.38	0.00	1.07	0.00	0.26	0.36	1.89	1.75	0.82
Total of taxa Hirudinea	**2**	**0**	**3**	**4**	**1**	**3**	**1**	**1**	**2**	**3**	**1**	**7**
Mollusca – Mussels:												
Gastropoda – Gastropods												
Anisus eichwaldi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Pyrgohydrobia dubia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Pyrgula (Caspia) gmelinii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Pyrgula (Caspiella) conus	0.00	0.00	0.00	0.79	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Pyrgula (Turricaspia) uralensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.02
Pyrgula sp.	8.95	0.00	0.00	5.16	3.36	6.68	6.52	5.94	3.30	3.18	4.97	4.40
Pseudamnicola brusiniana	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.02
Pseudamnicola sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.03
Theodoxus pallasi	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.15	0.05
Total of taxa Gastropoda	**1**	**0**	**1**	**2**	**2**	**1**	**2**	**2**	**1**	**5**	**3**	**9**
Bivalvia – Bivalves												
Mytilaster lineatus	0.00	0.00	0.99	2.38	1.29	0.53	0.00	0.09	0.00	0.00	0.15	0.30
Dreissena caspia	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Dreissena polymorpha	61.02	29.37	19.06	58.73	52.45	11.76	0.00	0.44	0.00	0.09	0.29	11.20
Didacna trigonoides	60.06	28.57	49.50	67.86	63.31	32.35	20.11	18.44	22.99	21.69	25.88	30.53
Didacna protracta	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.58	0.11
Didacna pyramidata	0.00	0.00	0.00	0.00	2.33	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Didacna sp.	0.64	0.00	0.50	0.40	0.00	0.00	0.00	0.00	0.00	0.09	0.44	0.14
Hypanis albida	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.15	0.05
Hypanis angusticostata	58.79	61.90	75.74	90.48	67.70	26.47	11.90	21.59	38.06	31.93	42.98	40.15
Hypanis caspia	7.99	0.79	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.52
Hypanis minima	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.02

Name of taxon	Frequency of occurrence, %											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
Hypanis vitrea	23.64	9.52	17.82	24.60	5.94	1.34	0.28	4.28	7.49	5.51	12.13	8.37
Hypanis sp.	0.32	0.00	6.93	0.00	0.26	0.27	0.57	0.61	0.00	0.09	1.61	0.82
Cerastoderma lamarcki	0.00	0.00	0.74	2.38	3.88	29.95	58.92	81.12	59.71	78.83	71.49	52.95
Abra ovata	38.98	75.40	77.48	89.29	91.21	96.52	96.03	92.92	86.72	89.76	95.32	87.63
Bivalvia gen.sp.	16.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.84
Total of taxa Bivalvia	**9**	**6**	**11**	**9**	**9**	**8**	**6**	**8**	**5**	**11**	**13**	**16**
Kamptozoa – Kamptozoa												
Barentsia benedeni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.05
Total of taxa Kamptozoa	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**
Arthropoda – Anthropods												
Crustacea – Shell fish												
Order of Anostraca – Anostracan												
Artemia sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.10
Total of taxa Anostraca	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**
Order of Cirripedia – Barnacles												
Balanus improvisus	25.56	12.70	44.06	65.48	51.16	51.07	50.42	43.09	38.86	42.94	50.88	44.01
Total of taxa Cirripedia	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Order of Mysidacea – Mysids												
Limnomysis benedeni	0.32	1.59	0.25	0.00	0.26	0.00	0.00	0.00	0.09	0.00	0.88	0.19
Mesopodopsis slabberi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	1.25	0.60	3.80	0.76
Mysis caspia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.34	0.00	0.08
Paramysis (Mesomysis) incerta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.02
Paramysis (Mesomysis) inflata	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Paramysis (Mesomysis) intermedia	0.00	0.00	0.00	1.59	0.00	0.27	0.00	0.61	2.05	0.26	0.44	0.65
Paramysis (Mesomysis) lacustris	3.51	3.17	4.21	3.17	0.78	1.87	3.97	5.51	9.98	2.24	4.97	4.73
Paramysis (Mesomysis) loxolepis	0.64	3.17	0.74	1.59	0.00	1.34	0.00	1.05	0.18	0.00	0.00	0.51
Paramysis (Metamysis) ullskyi	0.32	0.79	0.99	0.79	0.00	0.00	0.28	0.26	0.36	0.09	0.00	0.27
Paramysis (Paramysis) baeri	2.56	4.76	5.69	2.78	0.52	2.14	1.70	4.37	13.10	3.44	7.02	5.46
Paramysis sp.	0.32	0.00	0.50	0.79	0.26	0.53	0.00	0.09	0.45	0.00	0.15	0.24
Schistomysis elegans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.00	0.09	0.29	0.13
Caspiomysis knipowitschi	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.02
Mysidae gen.sp.	0.32	0.00	0.99	0.40	0.26	0.27	0.28	0.52	0.27	0.43	2.63	0.65
Total of taxa Mysidacea	**7**	**5**	**8**	**7**	**5**	**7**	**4**	**10**	**10**	**8**	**8**	**14**
Order of Cumacea – Cumaceans												
Schizorhynchus bilamellatus	76.68	38.89	78.47	87.70	68.99	60.96	55.81	64.86	73.35	60.33	48.98	65.18

Name of taxon	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
												Frequency of occurrence, %
Schizorhynchus eudorelloides	28.43	15.08	32.67	44.44	22.48	17.38	10.48	18.62	14.08	10.41	23.39	18.87
Schizorhynchus scabriusculus	94.25	80.95	82.67	86.11	69.51	29.68	10.20	13.20	14.62	4.73	15.35	29.09
Schizorhynchus sp.	0.00	0.00	0.50	0.79	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.17
Stenocuma diastyloides	0.00	0.00	0.00	0.00	0.00	0.00	0.85	0.09	0.00	0.60	1.61	0.35
Stenocuma gracilis	55.91	7.94	30.94	50.79	36.43	26.47	17.28	28.23	25.22	30.90	38.45	31.12
Stenocuma graciloides	76.36	72.22	79.46	87.30	66.15	66.84	80.45	86.89	68.27	70.22	77.92	75.46
Stenocuma sp.	0.00	0.00	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Stenocuma tenuicauda	0.00	0.00	0.25	0.00	0.78	0.27	0.00	0.00	0.27	0.00	1.17	0.25
Pseudocuma cercaroides	0.32	0.00	3.47	0.00	0.26	0.00	0.00	0.09	0.00	0.43	0.00	0.35
Pseudocuma laevis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	0.03
Pterocuma grandis	0.00	0.00	0.25	0.00	0.26	0.00	0.00	0.35	0.00	0.34	0.44	0.21
Pterocuma pectinata	21.73	18.25	69.06	82.14	52.71	76.47	87.82	92.66	91.27	88.64	87.13	80.48
Pterocuma rostrata	76.36	62.70	84.90	88.89	77.78	51.34	59.21	66.43	30.93	13.25	5.26	45.63
Pterocuma sowinskyi	4.79	0.00	0.50	2.38	3.62	2.14	0.85	0.00	0.36	0.17	1.17	0.98
Pterocuma sp.	0.32	0.00	0.25	0.79	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.09
Caspiocuma campylaspoides	31.63	19.05	43.32	54.37	21.19	10.43	5.10	14.95	25.67	15.75	20.91	21.50
Volgocuma telmatophora	3.83	3.97	5.20	3.57	4.91	0.53	0.28	1.57	3.57	1.46	4.09	2.72
Cumacea gen.sp.	0.00	0.00	0.25	0.00	0.00	0.00	0.28	0.00	0.00	0.34	2.34	0.35
Total of taxa Cumacea	**12**	**9**	**16**	**13**	**13**	**11**	**12**	**12**	**11**	**15**	**16**	**19**
Order of Amphipoda – Amphipods												
Akerogammarus contiguus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.03
Akerogammarus knipowitschi	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Amathillina pusilla	0.32	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Chaetogammarus macrocerus	0.00	0.00	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Chaetogammarus pauxillus	0.00	0.00	1.73	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Chaetogammarus warpachowskyi	7.99	3.17	8.42	4.37	3.10	1.07	0.00	0.09	0.18	2.41	0.88	2.01
Dikerogammarus caspius	0.32	0.79	0.50	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.08
Dikerogammarus haemobaphes	0.00	0.00	0.74	0.00	1.55	0.27	0.00	0.09	0.27	0.09	0.00	0.24
Gammarus subtypicus	0.00	0.00	1.24	0.00	0.00	1.07	0.28	1.31	0.36	0.17	0.15	0.51
Gmelina (Gmelina s.st.) costata	0.00	0.79	1.73	0.40	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.16
Gmelina (Kuzmelina) brachyura	5.43	0.00	2.72	2.38	0.26	1.34	0.57	0.00	0.00	0.00	0.00	0.66
Gmelina (Kuzmelina) laeviuscula	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.15	0.10
Gmelina (Yogmelina) pusilla	82.75	41.27	54.46	69.05	71.83	47.59	56.37	58.39	66.49	57.06	65.50	61.46
Gmelina sp.	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.15	0.06
Cardiophilus baeri	0.32	0.79	2.97	3.17	1.81	0.80	0.00	0.00	0.09	0.17	0.00	0.55

Name of taxon	Frequency of occurrence, %											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
Zernovia volgensis	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Niphargoides (Compactogammarus) compactus	1.28	0.79	3.71	0.79	2.33	0.00	1.13	0.26	0.36	0.17	0.15	0.71
Niphargoides (Niphargogammarus) aequimanus	2.88	0.00	5.94	5.95	1.81	0.00	0.28	1.14	1.34	1.64	2.63	1.91
Niphargoides (Niphargogammarus) derzhavini	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Niphargoides (Niphargogammarus) intermedius	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Niphargoides (Niphargogammarus) quadrimanus	9.58	8.73	13.61	9.92	6.72	2.41	3.40	5.42	8.91	12.82	2.19	7.82
Niphargoides (Niphargoides) borodini	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.03
Niphargoides (Niphargoides) caspius	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Niphargoides (Niphargoides) corpulentus	0.32	0.00	0.74	0.79	2.33	0.00	0.28	0.52	0.00	1.29	0.00	0.59
Niphargoides (Paraniphargoides) motasi	2.24	0.00	0.50	0.79	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.19
Niphargoides (Uroniphargoides) spinicaudatus	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Niphargoides sp.	0.32	1.59	13.12	8.33	0.00	0.00	0.00	0.09	0.00	0.52	0.73	1.41
Pontogammarus (Euxina) sarsi	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.09	0.00	0.00	0.15	0.05
Pontogammarus (Euxina) weidemanni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.02
Pontogammarus (Euxinia) maeoticus	0.00	0.00	1.73	0.40	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.14
Pontogammarus (Obesogammarus) crassus	0.00	0.00	0.00	0.40	1.55	0.27	0.28	0.17	0.27	0.00	0.00	0.22
Pontogammarus (Obesogammarus) obesus	0.00	1.59	3.71	3.97	5.68	0.80	4.25	4.11	0.98	0.34	0.00	2.04
Pontogammarus (Obesogammarus) paradoxus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.02
Pontogammarus (Pontogammarus) abbreviatus	1.92	0.79	2.97	3.57	2.84	0.27	0.57	1.75	1.34	0.17	0.00	1.25
Pontogammarus (Pontogammarus) robustoides	0.65	0.00	4.21	0.40	1.03	0.00	0.28	0.17	0.71	0.26	1.17	0.73
Pontogammarus sp.	0.00	0.79	6.93	4.37	1.81	0.27	0.85	0.00	0.18	0.09	1.75	1.04
Stenogammarus (Stenogammarus) compressus	1.28	0.00	4.95	6.75	1.55	0.53	2.27	8.65	5.44	4.56	2.92	4.59
Stenogammarus (Stenogammarus) deminutus	3.83	7.14	14.85	13.10	3.88	2.14	1.42	3.23	4.55	2.50	3.07	4.43
Stenogammarus (Stenogammarus) kereuschi	15.65	0.79	9.65	15.87	11.37	5.61	4.25	15.03	13.73	19.62	22.95	14.55

Name of taxon	Frequency of occurrence, %											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
Stenogammarus (Stenogammarus) macrurus	30.03	3.97	22.52	30.56	21.96	21.66	17.28	30.68	22.37	19.02	25.88	23.64
Stenogammarus (Stenogammarus) similis	71.57	39.68	55.69	76.98	60.21	40.37	53.26	52.88	62.83	60.93	53.07	57.68
Stenogammarus (Stenogammarus) sp.	0.00	2.38	27.23	17.86	1.03	1.87	1.98	0.96	0.71	0.52	6.73	3.91
Stenogammarus (Wolgogammarus) dzjubani	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.74	27.36	15.15	14.47	10.79
Shablogammarus shablensis	0.00	0.00	0.00	1.19	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.11
Pandorites platycheir	0.64	0.00	0.25	0.40	0.00	0.00	0.00	0.17	0.00	0.00	0.15	0.11
Pandorites podoceroides	1.28	0.79	0.25	1.59	0.52	0.00	0.00	0.52	0.00	0.00	0.00	0.28
Gammaridae gen.sp.	0.00	0.00	0.74	0.40	0.00	0.80	1.70	0.61	0.98	0.86	3.22	1.00
Caspicola knipowitschi	7.03	5.56	16.09	23.02	23.00	2.41	1.42	2.71	0.09	0.26	0.00	4.59
Corophium chelicorne	7.03	13.49	23.02	17.86	4.65	1.60	0.00	0.09	0.00	0.17	0.15	3.24
Corophium curvispinum	2.56	5.56	11.88	15.48	7.24	0.80	0.00	0.70	3.12	5.16	13.74	5.22
Corophium monodon	31.95	7.14	24.75	33.33	11.37	4.28	0.85	1.22	1.60	1.03	7.75	7.17
Corophium mucronatum	48.24	11.90	52.97	63.10	33.33	17.65	5.10	6.12	15.69	18.07	21.20	21.40
Corophium nobile	48.88	70.63	73.51	82.54	66.41	35.29	21.81	6.21	13.99	16.61	12.28	27.18
Corophium robustum	0.32	0.00	6.19	5.16	3.62	0.27	0.00	0.09	0.53	1.12	4.24	1.63
Corophium sowinskyi	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Corophium spinulosum	0.00	0.00	0.99	0.40	0.78	0.27	0.00	0.00	0.00	0.17	0.00	0.17
Corophium volutator	40.26	16.67	64.60	68.65	45.48	21.93	10.20	1.14	2.85	8.86	9.94	17.26
Corophium sp.	2.56	11.11	59.16	35.71	3.88	3.74	2.83	3.23	2.23	4.39	6.43	8.65
Total of taxa Amphipoda	**31**	**25**	**46**	**40**	**36**	**29**	**26**	**36**	**30**	**33**	**31**	**58**
Order of Isopoda – Isopodans												
Isopoda gen.sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02
Total of taxa Isopoda	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**
Order of Tanaidacea – Tanaides												
Tanaidae gen.sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.36	0.09	0.88	0.24
Total of taxa Tanaidacea	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**
Order of Decapoda – Decapods												
Palaemon adspersus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Palaemon elegans	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.02
Palaemon sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.03
Rhithropanopeus harrisii	23.64	56.35	49.50	32.14	30.23	25.94	24.93	34.88	29.14	33.22	41.52	33.60
Astacus leptodactylus eichwaldi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.02
Total of taxa Decapoda	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**5**

Name of taxon	Frequency of occurrence, %											
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total in the period
Arachnida – Arachnids												
Acariformes gen.sp.	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.05
Total of taxa Arachnida	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**
Insecta – Insects												
Potamanthus luteus	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Odonata gen.sp.sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	0.05
Limnebius sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.05
Coleoptera gen.sp.	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Clunio marinus	0.00	5.56	0.50	0.40	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.17
Cricotopus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.02
Tanytarsus gr.gregarius	0.00	0.00	0.00	1.19	0.00	0.00	0.00	0.09	0.09	0.00	0.29	0.11
Tanytarsus gr.mancus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.02
Tanytarsus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.36	0.00	0.00	0.10
Cladotanytarsus gr.mancus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.06
Chironomus albidus	7.03	14.29	2.48	3.57	2.07	0.80	2.83	6.12	6.33	1.03	1.02	3.80
Chironomus dorsalis	0.00	0.00	0.00	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Chironomus plumosus	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.05
Chironomus sp.	0.00	0.00	1.24	0.00	0.52	0.80	0.00	0.61	0.09	0.26	0.29	0.36
Cryptochironomus defectus	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.02
Microchironomus tener	0.00	0.00	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
Chironomidae gen.sp.	0.32	0.00	0.99	0.40	0.78	0.00	0.28	0.00	0.18	0.17	2.78	0.52
Atherix sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.05
Chrysops sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.02
Tricyphona (Tricyphona) immaculata	0.00	0.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.03
Ceratopogonidae gen.sp.	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Simuliidae gen.sp.	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Diptera gen.sp.	0.64	0.00	0.50	0.00	0.00	0.00	0.00	0.79	0.00	0.00	1.32	0.35
Total of taxa Insecta	**3**	**2**	**10**	**6**	**3**	**5**	**2**	**10**	**7**	**3**	**6**	**23**
Bryozoa – Byozoans												
Conopeum seurati	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.02
Total of taxa Bryozoa	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**
Total of taxa	**75**	**57**	**111**	**96**	**83**	**79**	**71**	**99**	**83**	**99**	**96**	**175**

Table A.6-2 Average annual dynamics of the macrozoobenthos main groups abundance in the North-East Caspian Sea in 2006-2016

	Vermes	Mollusca	Crustacea	Insecta	Others	Total
2006	12211	605	2712	31	67	15627
2008	9214	285	1713	75	63	11349
2009	8944	1126	4182	5	176	14433
2010	6890	812	2709	3	120	10533
2011	1774	594	617	1	77	3062
2012	2165	544	702	0	67	3479
2013	2910	439	791	1	28	4169
2014	3397	443	851	1	19	4712
2015	3510	1213	852	0	27	5602
2016	4304	407	1341	0	5	6058

Table A.6-3 Average annual dynamics of macrozoobenthos main groups biomass in the North-East Caspian Sea in 2006-2016

	Vermes	Mollusca	Crustacea	Insecta	Others	Total
2006	9923	9592	2591	44	3	22153
2008	8472	14222	4869	78	9	27649
2009	9242	26878	7286	12	50	43468
2010	7617	28149	4029	4	50	39849
2011	3103	19365	1620	2	34	24124
2012	1738	19037	1784	0	9	22568
2013	3344	35487	1558	1	16	40406
2014	4711	15134	1472	1	8	21326
2015	5712	17037	1705	0	7	24461
2016	7189	8924	2319	0	2	18435

ANNEX 7

Table A.7-1 Species composition of fish and frequency of its occurrence (%) in reference net catches, 2006-2016

		Number of species and frequency of its occurrence									
English name	**Latin name**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2013**	**2014**	**2015**	**2016**
Order Sturgeons	*Ordo Asipenseriformes*										
Family Sturgeons	*Familia Acipenseridae*	3	2	4	4	4	3	3	3	3	5
Beluga	*Huso huso*	7		2	8	3			1	1	2
Starred [stellate] sturgeon	*Acipenser stellatus*	51	38	46	43	23	23	5	1	7	17
Russian sturgeon	*Acipenser gueldenstaedtii*	68	44	77	49	40	15	20	6	21	30
Persian sturgeon	*Acipenser persicus*			17	8	13	8	1			1
Sterlet	*Acipenser ruthenus*										1
Order Herrings	*Ordo Clupeiformes*										
Family Herrings	*Familia Clupeidae*	4	4	5	6	4	4	4	4	6	4
Dolginsk Herring	*Alosa braschnikowi*	7		2	21	17			3	1	
Dolginka shad	*Alosa braschnikowi brashnikovi*		13					6		15	16
Caspian shad	*Alosa caspia caspia*	60	44		5	7	54	11	1	18	83
Black-backed [Volga, Caspian anadromous] shad	*Alosa kessleri*			3	5		31			1	
Big-eyed Shad Caspian	*Alosa saposchnikowii*	74	69	75	64	70	46	57	48	44	55
Agrakhana shad	*Alosa sphaerocephala*	61	44	38	75	60	46	38	66	39	59
Black Sea Sprat	*Clupeonella cultriventris*			5	2						
Order Esociformes	*Ordo Esociformes*										
Family Pices, pickerels	*Familia Esocidae*	1	0	1	0	1	0	0	0	0	0
Щука	*Esox lucius*	4		3		3					
Fromряд Карпообразные	*Ordo Cypriniformes*										
Семейство Карповые	*Familia Cyprinidae*	12	5	11	8	9	6	6	9	7	8
Pike (Northern)	*Rutilus rutilus*	100	100	100	98	97	100	99	100	100	92
Order Carps	*Rutilus frisii*	9									
Family Carps	*Leuciscus idus*	7									
Roach	*Scardinius erythrophthalmus*	14		3	8	3					
Black sea roach	*Leuciscus aspius*	47	63	26	28	13	23		19	18	34
Orfe, ide	*Tinca tinca*	7									
Rudds might	*Blicca bjoerkna*			3					3	1	5
Asp (Caspian, Aral).	*Abramis brama*	70	81	71	79	73	92	77	82	79	83
Tench	*Ballerus sapa*	70	38	14	31	20	31	3	10	3	1
Silver bream	*Abramis ballerus*	7		3		3			3		
Bream	*Pelecus cultratus*	65	31	28	26	17	38	16	19	17	38
White-eye bream	*Carassius carassius*			2							2
Blue bream	*Carassius auratus gibelio*	5		2	3	7		1	4		
Sabrefish, razorfish	*Cyprinus carpio*	18		9	11	13	8	19	23	6	20
Crucian carp	*Ordo Siluriformes*										
Prussian carp	*Familia Siluridae*	1	1	1	1	0	0	0	0	0	0
Sheatfish	*Silurus glanis*	12	6	2	2						
Order Mullet-like fish	*Ordo Mugiliformes*										
Family (gray) mullets	*Familia Mugilidae*	2	1	2	0	0	0	1	1	1	1
Golden [long-finned] grey mullet, golden millet	*Liza aurata*	11		5					3	8	17
Leaping gray mullet	*Liza saliens*	4	6	2				3			
Order Silversides	*Ordo Atheriniformes*										
Family Silversides, hardyheads	*Familia Atherinidae*	0	0	1	1	1	0	0	0	1	0
Silverside	*Atherina*			3	2	3				4	
Order Perch-like [spiny-finned] fish	*Ordo Perciformes*										
Famyli Perches, darters	*Familia Percidae*	3	1	2	1	1	1	1	1	1	2
Sander, zander, European pike-perch	*Sander lucioperca*	77	63	32	49	27	62	10	14	11	12
Volga zander	*Stizostedion volgensis*	18		2							
River perch	*Perca fluviatilis*	4									1
Famyli Gobies, gulgeons	*Familia Gobiidae*	6	4	7	4	3	2	2	2	2	0
Round goby	*Neogobius melanostomus*		6	17	11	7					
Syrman goby	*Neogobius syrman eurystomus*							2	1	1	
Monkey goby	*Neogobius fluviatilis*	39	13	52	33	27				7	
Caspian goby	*Neogobius caspius*	11	6	8		10	8				
Syrman goby	*Neogobius syrman*	18		2	3						
Big-headed goby	*Neogobius kessleri*	9	38	23							
Tube-nosed goby	*Proterorhinus marmoratus*	2		2	7						
Mahmudbekov's goby	*Bentophilus machmudbecov*	16									
Tadpole gobies	*Benthophilus sp.*			22							
Total number of species	*44*	30	17	32	24	22	16	17	20	21	20

Table A.7-2 Composition of fish species and frequency of its occurrence (%) in bottom trawl catches, 2006-2016

English name	Latin name	Number of species and frequency of its occurrence										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Order Sturgeons	*Ordo Asipenseriformes*											
Family Sturgeons	*Familia Acipenseridae*	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**
Starred [stellate] sturgeon	*Acipenser stellatus*					0.5						
Persian sturgeon	*Acipenser persicus*						0.7			0.2		
Order Herring-like	*Ordo Clupeiformes*											
Family (round) herrings, sardines	*Familia Clupeidae*	**4**	**2**	**3**	**2**	**3**	**2**	**3**	**4**	**4**	**4**	**5**
Dolginka shad	*Alosa braschnikowi brashnikovi*											7.5
Caspian shad	*Alosa caspia caspia*	2.2				8.4	21.9	0.6	1.6	0.2	2.3	13.5
Big eyed shad	*Alosa saposhnikovi*	2.9	12.1	2.8				0.6	0.6	0.2	2.3	2.4
Agrakhana shad	*Alosa sphaerocephala*	0.7		15.2	1.6	0.5			0.4	2.3	1.1	0.6
Black Sea Sprat	*Clupeonella cultriventris*	53.3	69.0	46.9	37.2	38.4	23.3	45.6	43.7	40.3	45.6	62.9
Order Carps	*Ordo Cypriniformes*											
Family Carps	*Familia Cyprinidae*	**6**	**5**	**5**	**6**	**5**	**6**	**5**	**6**	**4**	**6**	**8**
Roach	*Rutilus rutilus*	57.7	79.3	58.6	69.8	86.2	58.2	76.9	57.9	57.2	65.6	78.7
Asp (Caspian, Aral).	*Leuciscus aspius*				0.8	0.5	2.7	1.3	0.4		0.8	0.3
Danube bleak	*Alburnus chalcoides*										0.2	
Silver bream	*Blicca bjoerkna*											0.6
Bream	*Abramis brama*	8.8	37.9	24.8	14.0	20.7	28.8	18.1	14.8	11.1	16.9	36.2
White-eye bream	*Ballerus sapa*	5.8	13.8	2.8	1.6	2.0	0.7	0.6		0.2	0.2	
Blue bream	*Abramis ballerus*	5.1		0.7		0.5						1.5
Vimba	*Vimba vimba*											1.5
Sabrefish, razorfish	*Pelecus cultratus*	0.7	1.7	9.7	0.8		3.4	4.4	3.0	2.7	1.7	11.4
Prussian carp	*Carassius auratus gibelio*		1.7						0.4			
European, mirror carp	*Cyprinus carpio*	1.5			0.8		0.7		0.2			0.3
Cobitidae	*Familia Cobitidae*	0	1	1	1	1	0	0	0	1	0	0
Spined loach	*Cobitis taenia*									0.2		
Caspian spiny loach	*Sabanejewia caspia*		3.4	0.7	0.8	0.5						
Syngnthiformes	*Ordo Syngnthiformes*											
Family Pipefish, seahorses	*Familia Syngnathidae*	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Pipefish	*Syngnathus*	19.7	8.6	14.5	10.1	10.8	15.1	11.9	11.4	3.1	4.6	8.4
Order Mullet-like fish	*Ordo Mugiliformes*											
Family (gray) mullets	*Familia Mugilidae*	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**
Golden [long-finned] grey mullet, golden millet	*Liza aurata*										0.8	0.3
Leaping gray mullet	*Liza saliens*										0.4	
Order Silversides	*Ordo Atheriniformes*											
Family Silversides, hardyheads	*Familia Atherinidae*	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Silverside	*Atherina boyeri*	38.0	27.6	67.6	48.1	71.9	60.3	63.1	58.7	71.5	70.9	76.6
Order Perch-like [spiny-finned] fish	*Ordo Perciformes*											
Famyli Perches, darters	*Familia Percidae*	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**2**
Sander, zander, European pike-perch	*Sander lucioperca*	2.9	13.8	3.4	1.6	3.4	1.4			0.6		0.3
River perch	*Perca fluviatilis*											0.3
Famyli Gobies, gulgeons	*Familia Gobiidae*	**20**	**10**	**23**	**23**	**18**	**16**	**12**	**14**	**12**	**15**	**12**
Round goby	*Neogobius melanostomus*	16.1	22.4	27.6	26.4	20.2	11.6	0.6				
Neogobius caspius	*Neogobius caspius*			0.7			18.5	31.9	23.6	24.9	16.3	8.7

English name	Latin name	Number of species and frequency of its occurrence										
		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ratan goby	*Neogobius ratan*				0.8	0.5						
Monkey goby	*Neogobius fluviatilis*	84.7	91.4	95.2	85.3	91.1	82.2	81.3	76.8	82.0	76.2	79.3
Caspian goby	*Neogobius caspius*	13.9	13.8	3.4	19.4	32.0	21.2	10.0	11.2	4.0	3.0	2.1
Goad goby	*Neogobius gymnotrachelus*	28.5	31.0	60.0	35.7	22.2	19.2	2.5	1.2	1.3	8.2	2.4
Syrman goby	*Neogobius syrman*	10.2		5.5	7.0	13.8	30.8	2.5	8.0	0.6	4.0	0.0
Big-headed goby	*Neogobius kessleri*	24.1		17.2	32.6	22.2	21.9	26.3	19.0	12.2	21.7	11.4
Tube-nosed goby	*Proterorhinus marmoratus*	10.9	13.8	10.3	3.1		2.1	0.6	0.4		0.4	2.1
Caucasian dwarf goby	*Knipowitschia caucasica*	1.5			2.3		0.7	1.3				4.8
Longtail dwarf goby	*Knipowitschia longecaudata*	59.1	81.0	53.1	42.6	4.4	14.4	15.0	23.4	32.1	20.5	20.1
Ilyin's goby	*Knipowitschia iljini*	20.4	44.8	12.4	4.7		2.1	1.3	3.4	4.4	5.5	10.8
Berg's goby	*Hyrcanogobius bergi*	2.9		6.2		1.0			1.2	1.5	1.5	1.8
Caspianososma	*Caspiosoma caspium*	13.1	6.9	9.7	21.7	0.5	0.7					0.3
Bighead goby	*Benthophilus macrocephalus*	19.0		20.0	2.3	11.8	2.1	5.6	4.6	7.1	4.4	13.5
Azov tadpole goby	*Benthophilus magistri*	3.6	51.7	29.7	15.5	9.9			0.2		0.8	
Abdurahmanov's goby	*Benthophilus magistri abdurahmanovi*	7.3			2.3							
Mahmudbeev's goby	*Benthophilus mahmudbejovi*	38.7	67.2	9.0	8.5	1.5	1.4		0.4	0.4	0.2	
Spike-headed goby	*Benthophilus ctenolepidus*			1.4	0.8							
Benthophilus stellatus	*Benthophilus stellatus*	5.1		1.4	3.1	2.5	0.7				0.2	
Benthophilus casachicus	*Benthophilus casachicus*				0.8							
Benthophilus spinosus	*Benthophilus spinosus*			0.7								
Benthophilus leptocephalus	*Benthophilus leptocephalus*			1.4								
Benthophilus granulosus	*Benthophilus granulosus*	0.7									1.5	
Benthophilus leptorhynchus	*Benthophilus leptorhynchus*	3.6										
Benthophilus grimmi	*Benthophilus grimmi*	1.5		4.1	3.1	0.5						
Benthophilus svetovidovi	*Benthophilus svetovidovi*			1.4	0.8	1.0						
Benthophilus kessleri	*Benthophilus kessleri*			13.8	3.9	5.9						
Tadpole goby	*Benthophilus sp.*			5.5	3.9	0.5	0.7		0.2	1.3		
Total number of species	*53*	**33**	**21**	**35**	**35**	**31**	**28**	**22**	**26**	**25**	**29**	**30**

Table A.7-3 Abundance of fish of the nektonic fish community in net catches, 2006-2016 (specimen/effort)

Type of fish	2006	2007	2008	2009	2010	2011	2013	2014	2015	2016
Beluga	0.89		0.11	0.83	0.20			0.06	0.11	0.17
Stellate sturgeon	6.37	4.46	9.46	5.82	2.36	1.53	0.31	0.09	0.68	1.47
Bastard sturgeon	0.18									
Russian sturgeon	29.04	8.99	21.75	9.73	7.22	1.09	6.15	0.77	2.62	3.89
Persian sturgeon			2.16	0.59	0.85	0.52	0.08			0.09
Sterlet										0.07
Herring	1.56		0.11	3.31	4.03			1.56	1.64	
Dolginka shad		4.79					1.55		4.14	39.20
North-Caspian shad	12.67	4.45		0.79	1.80	13.23	1.44	0.09	2.15	192.81
Caspian anadromous shad						3.74			0.20	
Blackback shads			0.23	0.73						
Big-eyed Shad Caspian	52.70	41.17	147.12	50.29	72.53	4.78	29.84	51.30	40.85	298.75
Agrakhana shad	18.63	8.82	9.83	48.52	30.33	18.73	10.93	21.30	17.51	36.46
Black Sea-Caspian Kilkas			0.34	0.12						
Pike (Northern)	0.26		0.19		0.17					
Roach	356.00	362.81	304.05	436.68	273.06	381.15	364.57	341.77	378.27	326.33
Black sea roach	1.07									
Orfe, ide	5.81									
Rudds might	155.47		1.02	4.13	0.35					
Asp (Caspian, Aral).	8.95	24.45	3.14	3.46	1.89	1.55		2.22	5.35	10.16
Tench	1.39									
Silver bream			1.48					1.08	0.22	14.10
Bream	73.14	44.93	22.91	66.39	79.83	85.02	50.94	84.94	79.57	70.73
White-eye bream	44.49	10.61	17.73	4.82	8.98	3.98	0.44	1.54	0.19	0.08
Blue bream	0.89		4.17		0.52			1.48		
Sabrefish, razorfish	10.91	11.02	5.01	2.59	1.82	5.67	2.79	3.31	2.82	9.48
Crucian carp			0.11							0.17
Prussian carp	1.58		0.08	0.39	0.63		0.09	0.88		
European, mirror carp	32.40		3.18	0.97	13.50	0.95	4.74	5.69	1.03	2.27
Sheatfish	1.37	0.46	0.11	0.13						
Ukrainian stickleback	0.12									
Pipefish	0.23									
Golden [long-finned] grey mullet, golden millet	2.05		0.45					0.19	0.83	2.63
Leaping gray mullet	0.25	0.50	0.11				0.42			
silverside			0.22	0.12	0.53				0.43	
Sander, zander, European pike-perch	36.91	15.95	5.39	13.53	14.50	22.52	1.25	1.40	1.63	4.00
Volga zander	3.30		0.08							
River perch	0.25									0.08
Round goby		1.00	3.39	1.44	0.70					
monkey goby	8.44	0.86	10.18	48.13	86.46				1.20	
Caspian goby	1.54	0.50	0.67		0.70	1.12				
Syrman goby	2.54		0.11	0.24			0.15	0.19	0.43	
Big-headed goby	0.70	5.23	2.85			0.55	0.16	0.27		
Tube-nosed goby	0.11		0.33	1.59						
Ilyin's goby				0.11						
Bighead goby					0.45					
Mahmudbeev's goby	1.33									
Benthophilus stellatus	0.12									
Tadpole goby			2.84							

Table A.7-4 Fish abundance of the benthic pelagic fish community in trawl catches, 2006-2016 (specimen/hec)

Type of fish	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Stellate sturgeon					0.04						
Persian sturgeon						0.04			0.01		
Dolginka shad											1.11
North-Caspian shad	0.16				0.86	8.16	0.04	0.12	0.01	0.52	2.24
Big-eyed Shad Caspian	0.43	1.16	0.22				0.04	0.05	0.02	0.19	9.73
Agrakhana shad	0.06		23.14	0.31	0.04			0.03	0.48	0.08	0.04
Black Sea-Caspian Kilkas	280.78	89.85	139.60	165.44	52.37	4.22	149.61	73.44	76.14	140.31	220.55
Roach	46.49	82.29	60.81	107.08	182.17	143.65	92.53	71.21	50.86	101.60	199.25
Asp (Caspian, Aral).				0.06	0.03	0.18	0.08	0.02		0.05	0.02
Chalcalburnus chalcoides										0.01	
Silver bream											0.23
Bream	2.99	9.48	6.59	3.48	2.70	8.01	2.54	2.82	1.90	3.37	13.08
White-eye bream	1.51	1.73	0.87	0.13	1.90	0.05	0.04		0.02	0.07	
Blue bream	2.91		0.21		0.03						0.30
Vimba											0.09
Sabrefish, razorfish	0.04	1.09	0.82	0.06		0.27	0.28	0.26	0.22	0.12	15.25
Prussian carp		1.27						0.03			
European, mirror carp	0.20			0.06		0.04		0.06			0.02
Spined loach									0.23		
Caspian spiny loach		0.80	0.31	0.35	0.45						
Pipefish	3.44	0.58	1.99	3.12	1.08	5.55	2.33	1.49	0.49	0.35	0.67
Golden [long-finned] grey mullet, golden millet										0.06	0.02
Leaping gray mullet										0.02	
silverside	23.77	5.88	74.88	178.18	80.70	77.43	88.37	52.49	126.11	86.17	189.05
Sander, zander, European pike-perch	0.42	2.70	0.30	0.12	0.28	0.55			0.05		0.02
Leaping gray mullet											0.02
Silverside	3.84	4.68	9.46	5.14	2.58	3.36	0.04				
Neogobius caspius			0.12			5.31	12.00	4.13	5.86	3.49	1.66
Ratan goby				0.06	0.04						
Monkey goby	483.61	617.67	771.16	556.00	319.87	215.73	283.77	145.21	234.28	137.85	331.07
Caspian goby	2.94	2.06	0.28	3.78	7.93	4.75	0.91	1.28	0.48	0.26	0.45
Goad goby	21.95	92.74	404.23	112.68	6.95	4.40	0.58	0.56	0.24	1.81	0.29
Syrman goby	3.02		0.68	1.04	2.01	8.00	0.75	1.47	0.24	1.33	
Big-headed goby	5.44		3.48	19.93	3.76	3.97	6.47	3.79	1.94	7.07	8.72
Tube-nosed goby	7.07	2.39	1.55	4.41		5.73	0.25	0.13		0.04	0.94
Caucasian dwarf goby	0.18			4.55		0.26	0.08				0.43
Longtail dwarf goby	32.29	204.61	25.58	36.56	0.44	16.38	3.24	10.93	45.78	9.00	5.04
Ilyin's goby	3.55	9.98	2.25	2.50		0.98	0.07	2.14	2.16	2.65	2.90
Berg's goby	0.46		0.94		1.16			0.69	0.68	0.13	0.31
Caspianososma	2.10	0.67	1.68	9.92	0.03	0.29					0.09
Bighead goby	10.89		5.36	0.24	2.92	0.54	1.32	0.89	1.20	3.79	6.66
Azov tadpole goby	0.83	71.26	21.66	5.85	1.53			0.01		0.31	

Type of fish	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Abdurahmanov's goby	2.23			0.82							
Mahmudbeev's goby	11.81	43.29	2.88	3.08	0.17	0.09		0.03	0.08	0.01	
Spike-headed goby			0.19	0.06							
Benthophilus stellatus	0.96		0.20	1.05	0.21	0.43				0.04	
Benthophilus casachicus				0.24							
Benthophilus spinosus			0.06				0.09				
Benthophilus leptocephalus			0.11								
Benthophilus granulosus	0.08									0.16	
Benthophilus leptorhynchus	2.40										
Benthophilus grimmi	0.19		1.11	0.38	0.03						
Benthophilus svetovidovi			0.11	0.06	0.11						
Benthophilus kessleri			2.58	0.76	1.46						
Tadpole goby			0.80	1.02	0.04	0.05		0.03	0.27		

ANNEX 8

Table A.8-1 List of birds encountered in Kashagan in spring and autumn seasons 2009-2016 and their recorded number for the entire observations period

№	Latin name	English name	Autumn	Spring
	Podiceps nigricollis	Black-Necked Grebe	6	3
	Podiceps auritus	Slavonian Grebe	3	
	Podiceps griseigena	Red-Necked Grebe	17	
	Podiceps cristatus	Great Crested Grebe	9	7
	*Pelecanus crispus**	**Dalmatian Pelican**		**3**
	Phalacrocorax carbo	Great Cormorant	846	325
	Botaurus stellaris	Bittern		1
	Nycticorax nycticorax	Night Heron		3
	Egretta alba	Great Egret		5
	Ardea cinerea	Grey Heron	23	40
	Ardea purpurea	Purple Heron		8
	*Platalea leucorodia**	**Spoonbill**		**1**
	*Plegadis falcinellus**	**Glossy Ibis**	**60**	**299**
	Anser anser	Graylag Goose		1
	Anser albifrons	Greater white-fronted goose	180	
	Cygnus olor	Mute Swan	303	14
	*Cygnus cygnus**	**Whooper Swan**	**54**	
	Tadorna ferruginea	Ruudy Shelduck	1	
	Tadorna tadorna	Shelduck	8	23
	Anas platyrhynchos	Mallard	5	2
	Anas crecca	Teal	8	31
	Anas strepera	Gadwall		1
	Anas penelope	Wigeon	10	
	Anas acuta	Pintail	17	9
	Anas querquedula	Garganey	1	2
	Anas clypeata	Shoveler		4
	Netta rufina	Red-Crested Pochard	2	70
	Aythya ferina	Pochard	34	
	Aythya fuligula	Tufted Duck		2
	Clangula hyemalis	Long-Tailed Duck		7
	Bucephala clangula	Goldeneye		101
	Mergus albellus	Smew	1	1
	Mergus serrator	Red-Breasted Merganser	25	
	Mergus merganser	Goosander	17	
	*Pandion haliaetus**	**Osprey**	**1**	
	Pernis apivorus	Honey Buzzard	9	
	Milvus migrans	Black Kite	2	7
	Circus cyaneus	Hen Harrier	11	1
	Circus macrourus	Pallid Harrier	6	12
	Circus pygargus	Montagu's Harrier		5
	Circus aeruginosus	Marsh Harrier	4	5
	Accipiter nisus	Sparrowhawk	66	16
	Buteo lagopus	Rough-legged buzzard	2	
	Buteo rufinus	Long-Legged Buzzard	3	1
	Buteo buteo	Common Buzzard	7	5
	*Aquila nipalensis**	**Steppe Eagle**	**4**	**1**
	*Haliaeetus albicilla**	**White-Tailed Eagle**	**7**	**5**
	*Falco cherrug**	**Saker Falcon**	**3**	
	*Falco peregrinus**	**Peregrine Falcon**	**7**	
	Falco subbuteo	Hobby	27	
	Falco columbarius	Merlin	3	6
	Falco vespertinus	Red-footed falcon	1	1
	Falco naumanni	Lesser Kestrel	11	
	Falco tinnunculus	Kestrel	47	73
	Coturnix coturnix	Quail	30	1
	Porzana parva	Spotted Crake	1	1
	Gallinula chloropus	Common moorhen		2
	Fulica atra	Coot	1	1
	*Tetrax tetrax**	Little Bustard	1	4

№	Latin name	English name	Autumn	Spring
	Burhinus oedicnemus	Eurasian stone-curlew		40
	Charadrius hiaticula	Ringed Plover	1	1
	Charadrius dubius	Little Ringed Plover		2
	Eudromias morinellus	Eurasian dotterel		1
	Vanellus vanellus	Northern lapwing	8	
	Vanellochettusia leucura	White-tailed lapwing		3
	Arenaria interpres	Ruddy turnstone		2
	Himantopus himantopus	Black-Winged Stilt		2
	Tringa ochropus	Green Sandpiper	1	8
	Tringa totanus	Redshank		7
	Tringa stagnatilis	Marsh Sandpiper		1
	Actitis hypoleucos	Common Sandpiper	8	12
	Phalaropus lobatus	Red-Necked Phalarope	1	1
	Philomachus pugnax	Ruff	6	49
	Calidris alpina	Dunlin	17	5
	Limnocryptes minimus	Jack Snipe		1
	Gallinago gallinago	Common Snipe	4	6
	Scolopax rusticola	Common Woodcock	4	2
	Numenius phaeopus	Whimbrel		36
	Limosa limosa	Black-Tailed Godwit		19
	Limosa lapponica	Bar-Tailed Godwit		1
	Stercorarius parasiticus	Parasitic Skua		2
	*Larus ichthyaetus**	**Great Black-Headed Gull**	546	605
	Larus ridibundus	Common Black-Headed Gull	289	2236
	Larus genei	Slender-billed Gull	3	68
	Larus fuscus	Lesser Black-Backed Gull		6
	Larus heuglini	Heuglin's Gull	8	33
	Larus cachinnans	Herring Gull	866	2655
	Larus hyperboreus	Glaucous Gull		1
	Larus canus	Common Gull	140	30
	Rissa trydactyla	Black-Legged Kittiwake		2
	Gelochelidon nilotica	Gull-Billed Tern		4
	Hydroprogne caspia	Caspian Tern	16	69
	Thalasseus sandvicensis	Sandwich Tern		2912
	Sterna hirundo	Common Tern	69	6083
	*Pterocles orientalis**	**Black-Bellied Sandgrouse**		2
	Columba palumbus	Wood Pigeon		1
	Columba oenas	Stock Dove	2	5
	Columba eversmanni	Yellow-eyed pigeon		2
	Columba livia	Rock Dove		3
	Streptopelia decaocto	Collared Dove	18	4
	Streptopelia orientalis	Eastern Turtle Dove	7	
	Streptopelia senegalensis	Laughing Dove	1	
	Asio otus	Long-Eared Owl	3	9
	Asio flammeus	Short-Eared Owl	3	20
	Caprimulgus europaeus	Nightjar	3	
	Alcedo atthis	Kingfisher	2	3
	Merops superciliosus	Blue-Cheeked Bee-Eater	52	
	Upupa epops	Hoopoe	1	55
	Junx torquila	Eurasian wryneck		1
	Riparia riparia	Sand Martin	7	11
	Riparia diluta	Pale martin	29	3
	Hirundo rustica	Barn Swallow	210	40
	Hirundo daurica	Red-rumped Swallow		1
	Delichon urbica	House Martin		5
	Galerida cristata	Crested Lark	17	13
	Calandrella brachydactyla	Short-Toed Lark	15	950
	Calandrella rufescens	Lesser Short-Toed Lark	12	51
	Melanocorypha calandra	Calandra Lark	17	91
	Melanocorypha bimaculata	Bimaculated Lark		2
	Melanocorypha leucoptera	White-Winged Lark		1
	Alauda arvensis	Skylark	14	802
	Anthus trivialis	Tree Pipit		13
	Anthus campestris	Tawny Pipit	3	8
	Anthus hodgsoni	Olive-backed pipit		4
	Anthus pratensis	Meadow pipit	6	20
	Anthus cervinus	Red-Throated Pipit	5	

№	Latin name	English name	Autumn	Spring
	Motacilla flava	Yellow Wagtail	20	116
	Motacilla feldegg	Black-Headed Wagtail	1	18
	Motacilla lutea	Yellow 'Lutea' Wagtail	1	7
	Motacilla citreola	Citrine Wagtail	2	243
	Motacilla cinerea	Gray Wagtail	1	4
	Motacilla alba	White Wagtail	2000	540
	Lanius excubitor	Great Grey Shrike		28
	Lanius phoenicuroides	Turkestan Isabelline Shrike	46	
	Lanius collurio	Red-Backed Shrike	28	
	Sturnus vulgaris	Starling	58	280
	Corvus monedula	Jackdaw	9	17
	Corvus frugilegus	Rook	60	844
	Corvus cornix	Hooded Crow	67	105
	Prunella modularis	Dunnock		1
	Cettia cetti	Cetti's Warbler	1	
	Acrocephalus agricola	Paddy-Field Warbler	10	5
	Acrocephalus dumetorum	Blyth's Reed Warbler	8	
	Acrocephalus palustris	Marsh Warbler	2	
	Hippolais caligata	Booted Warbler	1	
	Sylvia borin	Garden Warbler	54	
	Sylvia communis	Whitethroat	33	
	Sylvia atricapilla	Eurasian blackcap		1
	Sylvia curruca	Lesser Whitethroat		43
	Sylvia mystacea	Menetries's Warbler	1	
	Phylloscopus trochilus	Chiffchaff	14	
	Phylloscopus collybita	Wood Warbler		59
	Phylloscopus trochiloides viridanus	Greenish Warbler	6	
	Regulus regulus	Goldcrest	7	
	Ficedula hypoleuca	Pied Flycatcher		1
	Ficedula parva	Red-Breasted Flycatcher	147	
	Muscicapa striata	Spotted Flycatcher	33	
	Saxicola rubetra	Whinchat	6	8
	Saxicola torquata	Stonechat		1
	Oenanthe oenanthe	Wheatear	130	58
	Oenanthe pleshanka	Pied Wheatear		6
	Oenanthe isabellina	Isabelline Wheatear	8	16
	Phoenicurus ochruros	Black Redstart	2	21
	Phoenicurus phoenicurus	Redstart	134	14
	Erithacus rubecula	Robin	42	42
	Luscinia svecica	Bluethroat		107
	Luscinia megarhynchos	Common nightingale	8	
	Luscinia luscinia	Thrush nightingale	1	
	Turdus atrogularis	Black-throated thrush		4
	Turdus pilaris	Fieldfare		5
	Turdus merula	Blackbird	2	14
	Turdus philomelos	Song Thrush	97	136
	Turdus viscivorus	Mistle Thrush	7	58
	Parus major	Great Tit	41	
	Panurus biarmicus	Bearded reedling		2
	Certhia familiaris	Treecreepers	1	
	Passer domesticus	House Sparrow	14	7
	Passer montanus	Tree Sparrow	104	42
	Fringilla coelebs	Chaffinch	78	228
	Fringilla montifringilla	Brambling	6	53
	Spinus spinus	Eurasian siskin	46	5
	Acanthis flavirostris	Twite	9	
	Carpodacus erythrinus	Common rosefinch	19	
	Emberiza citrinella	Yellowhammer	7	8
	Emberiza schoeniclus	Common reed bunting	7	13
	Emberiza hortulana	Ortolan bunting		1
	Emberiza bruniceps	Red-headed bunting	2	

Note: *species included in Kazakhstan's Red Book are marked in bold and**

[1] *Spring monitoring took on average 5 days in April, in total 51 days for all years, in autumn – in total 39 days with the largest number of days in September*

Table A.8-2 A systematic list of birds recorded from the scientific research vessels (SRV) during environmental monitoring in the open water of the North-East Caspian Sea and at the Company's offshore facilities in the period 2012-2016

Orders and species of birds

English name	Latin name	English name	Latin name	English name	Latin name
		Loons - Gaviiformes			
Red-Throated Loon	*Gavia stellata*	Black-Throated Loon	*Gavia arctica*		
		Grebes - Podicepediformes			
Little grebe	*Podiceps ruficollis*	Black-necked grebe	*Podiceps nigricollis*	Slavonian Grebe	*Podiceps auritus*
Red-necked grebe	*Podiceps griseigena*	Great crested grebe	*Podiceps cristatus*		
		Cormorants - Pelecaniformes			
White Pelican*	*Pelecanus onocrotalus*	**Dalmatian Pelican***	*Pelecanus crispus*	Great Cormorant	*Phalacrocorax carbo*
Pygmy Cormorant	*Phalacrocorax pygmeus*				
		Ciconiiformes			
Bittern	*Botaurus stellaris*	Night Heron	*Nycticorax nycticorax*	Great Egret	*Egretta alba*
Little Egret*	*Egretta garzetta*	Grey Heron	*Ardea cinerea*	Purple Heron	*Ardea purpurea*
Eurasian Spoonbill*	*Platalea leucorodia*	**Glossy ibis***	*Plegadis falcinellus*		
		Flamingoes - Phoenicopteriformes			
Greater flamingo*	*Phoenicopterus roseus*				
		Waterfowl - Anseriformes			
Greylag goose	*Anser anser*	Taiga bean goose	*Anser fabalis*	Mute Swan	*Cygnus olor*
Hooping swan*	*Cygnus cygnus*	Ruddy shelduck	*Tadorna ferruginea*	Common shelduck	*Tadorna tadorna*
Mallard	*Anas platyrhynchos*	Teal	*Anas crecca*	Garganey	*Anas querquedula*
Wigeon	*Anas penelope*	Pintail	*Anas acuta*	Shoveler	*Anas clypeata*
Red-Crested Pochard	*Netta rufina*	Pochard	*Aythya ferina*	Tufted Duck	*Aythya fuligula*
Scaup	*Aythya marila*	Long-Tailed Duck	*Clangula hyemalis*	Goldeneye	*Bucephala clangula*
Velvet Scoter*	*Melanitta fusca*	Smew	*Mergus albellus*	Red-Breasted Merganser	*Mergus serrator*
Большой крохаль	*Mergus merganser*				
		Falcons and Caracaras - Falconiformes			
Osprey*	*Pandion haliaetus*	European honey buzzard	*Pernis apivorus*	Black kite	*Milvus migrans*
Hen harrier	*Circus cyaneus*	Pallid harrier	*Circus macrourus*	Montagu's harrier	*Circus pygargus*
Western marsh harrier	*Cyrcus aeruginosus*	Northern goshawk	*Accipiter gentilis*	Eurasian sparrowhawk	*Accipiter nisus*
Levant sparrowhawk	*Accipiter brevipes*	Long-legged buzzard	*Buteo rufinus*	Common buzzard	*Buteo buteo*
Steppe eagle*	*Aquila nipalensis*	**Eastern imperial eagle**	*Aquila heliaca*	**White-tailed eagle***	*Haliaeetus albicilla*
Saker falcon*	*Falco cherrug*	**Barbary falcon***	*Falco pelegrinoides*	**Peregrine falcon***	*Falco peregrinus*
Hobby	*Falco subbuteo*	Merlin	*Falco columbarius*	Lesser kestrel	*Falco naumanni*
Kestrel	*Falco tinnunculus*				
		Landfowl – Galliformes			
Quail	*Coturnix coturnix*				
		Gruiformes			
Common Crane	*Grus grus*	Spotted crake	*Porzana porzana*	Crook	*Fulica atra*
Little bustard*	*Tetrax tetrax*				
		Shorebirds - Charadriiformes			
Grey plover	*Pluvialis squatarola*	Ringed plover	*Charadrius hiaticula*	Little Ringed Plover	*Charadrius dubius*

Orders and species of birds

English name	Latin name	English name	Latin name	English name	Latin name
Kentish Plover	*Charadrius alexandrinus*	Caspian Plover	*Charadrius asiaticus*	Turnstone	*Arenaria interpres*
Black-Winged Stilt	*Himantopus himantopus*	Pied Avocet	*Recurvirostra avosetta*	Oystercatcher	*Haematopus ostralegus*
Green sandpiper	*Tringa ochropus*	Wood sandpiper	*Tringa glareola*	Greenshank	*Tringa nebularia*
Common redshank	*Tringa totanus*	Spotted Redshank	*Tringa erythropus*	Marsh Sandpiper	*Tringa stagnatilis*
Terek sandpiper	*Xenus cinereus*	Red-necked phalarope	*Phalaropus lobatus*	Northern lapwing	*Vanellus vanellus*
Little Stint	*Calidris minuta*	Temminck's stint	*Calidris temminckii*	Ox-bird	*Calidris sp.*
Common Snipe	*Gallinago gallinago*	Sanderling	*Calidris alba*	Ruff	*Philomachus pugnax*
Common Woodcock	*Scolopax rusticola*	Dunlin	*Calidris alpina*	Curlew Sandpiper	*Calidris ferruginea*
Common Sandpiper	*Actitis hypoleucos*	Curlew	*Numenius arquata*	Whimbrel	*Numenius phaeopus*
Black-Tailed Godwit	*Limosa limosa*	Bar-Tailed Godwit	*Limosa lapponica*	Black-Winged Pratincole	*Glareola nordmanni*
Parasitic Skua	*Stercorarius parasiticus*	Pomarine Skua	*Stercorarius pomarinus*	Great Black-Headed Gull*	*Larus ichthyaetus*
Little Gull	*Larus minutus*	Common Black-Headed Gull	*Larus ridibundus*	Slender-billed Gull	*Larus genei*
Lesser Black-Backed Gull	*Larus fuscus*	Heuglin's Gull	*Larus heuglini*	Herring Gull	*Larus argentatus*
Caspian gull	*Larus cachinnans*	Glaucous Gull	*Larus hyperboreus*	Common Gull	*Larus canus*
Black-Legged Kittiwake	*Rissa trydactyla*	Mediterranean gull	*Larus melanocephalus*	Black Tern	*Chlidonias niger*
White-Winged Tern	*Chlidonias lercopterus*	Whiskered Tern	*Chlidonias hybridus*	Gull-Billed Tern	*Gelochelidon nilotica*
Caspian Tern	*Hydroprogne caspia*	Sandwich tern	*Thalasseus sandvicensis*	Common Tern	*Sterna hirundo*
Little Tern	*Sterna albifrons*				
Sandgrouse - Pterocletiformas					
Black-Bellied Sandgrouse*	*Pterocles orientalis*				
Columbiformes					
Wood Pigeon	*Columba palumbus*	Stock Dove	*Columba oenas*	Rock Dove	*Columba livia*
Collared Dove	*Streptopelia decaocto*	Turtle Dove	*Streptopelia turtur*	Eastern Turtle Dove	*Streptopelia orientalis*
Laughing Dove	*Streptopelia senegalensis*				
Caprimulgiformes					
Nightjar	*Caprimulgus europaeus*				
Owl - Strigiformes					
Long-Eared Owl	*Asio otus*	Short-Eared Owl	*Asio flammeus*		
Apodiformes					
Common swift	*Apus apus*				
Coraciiformes					
Kingfisher	*Alcedo atthis*	European Bee-Eater	*Merops apiaster*	Blue-Cheeked Bee-Eater	*Merops superciliosus*
Upupiformes					
Hoopoe	*Upupa epops*				
Passerine – Passeriformes					
Sand Martin	*Riparia riparia*	House Martin	*Delichon urbica*	Swallow	*Hirundo rustica*
Crested Lark	*Galerida cristata*	Short-Toed Lark	*Calandrella brachydactyla*	Lesser Short-Toed Lark	*Calandrella rufescens*
Calandra Lark	*Melanocorypha calandra*	Bimaculated Lark	*Melanocorypha bimaculata*	White-Winged Lark	*Melanocorypha leucoptera*
Black Lark	*Melanocorypha yeltoniensis*	Skylark	*Alauda arvensis*	Horned Lark	*Eremophila alpestris*
Tawny Pipit	*Anthus campestris*	Tree Pipit	*Anthus trivialis*	Meadow Pipit	*Anthus pratensis*

Orders and species of birds

English name	Latin name	English name	Latin name	English name	Latin name
Red-Throated Pipit	*Anthus cervinus*	Yellow Wagtail	*Motacilla flava*	Black-Headed Wagtail	*Motacilla feldegg*
Yellow 'Lutea' Wagtail	*Motacilla lutea*	Citrine Wagtail	*Motacilla citreola*	Gray Wagtail	*Motacilla cinerea*
White Wagtail	*Motacilla alba*	Red-Backed Shrike	*Lanius collurio*	Turkestan Isabelline Shrike	*Lanius phoenicuroides*
Lesser Grey Shrike	*Lanius minor*	Steppe shrike	*Lanius meridionalis*	Great Grey Shrike	*Lanius excubitor*
Golden Oriole	*Oriolus oriolus*	Starling	*Sturnus vulgaris*	Rose-Colloured Starling	*Sturnus roseus*
Nutcracker	*Nucifraga caryocatactes*	Jackdaw	*Corvus monedula*	Rook	*Corvus frugilegus*
Carrion Crow	*Corvus corone*	Hooded Crow	*Corvus cornix*	Raven	*Corvus corax*
Waxwings	*Bombycilla garrulus*	Wren	*Troglodytes troglodytes*	Cetti's Warbler	*Cettia cetti*
Grasshopper	*Locustella naevia*	Moustached Warbler	*Acrocephalus melanopogon*	Sedge Warbler	*Acrocephalus schoenobaenus*
Marsh Warbler	*Acrocephalus palustris*	Paddy-Field Warbler	*Acrocephalus agricola*	Blyth's Reed Warbler	*Acrocephalus dumetorum*
Reed Warbler	*Acrocephalus scirpaceus*	Olivaceous Warbler	*Hippolais pallida*	Sikes Booted Warbler	*Hippolais rama*
Booted Warbler	*Hippolais caligata*	Upcher's Warbler	*Hippolais languida*	Barred Warbler	*Sylvia nisoria*
Whitethroat	*Sylvia communis*	Garden Warbler	*Sylvia borin*	Lesser Whitethroat	*Sylvia curruca*
Menetries's Warbler	*Sylvia mystacea*	Willow Warbler	*Phylloscopus trochilus*	Chiffchaff	*Phylloscopus collybita*
Wood Warbler	*Phylloscopus sibilatrix*	Greenish Warbler	*Phylloscopus trochiloides*	Goldcrest	*Regulus regulus*
Pied Flycatcher	*Ficedula hypoleuca*	Red-Breasted Flycatcher	*Ficedula parva*	Spotted Flycatcher	*Muscicapa striata*
Whinchat	*Saxicola rubetra*	Stonechat	*Saxicola torquatus*	Wheatear	*Oenanthe oenanthe*
Isabelline Wheatear	*Oenanthe isabellina*	Pied Wheatear	*Oenanthe pleshanka*	Black-Eared Wheatear	*Oenanthe hispanica*
Redstart	*Phoenicurus phoenicurus*	Black Redstart	*Phoenicurus ochrurus*	Robin	*Erythacus rubecula*
Thrush nightingale	*Luscinia luscinia*	Bluethroat	*Luscinia svecica*	Fieldfare	*Turdus pilaris*
Blackbird	*Turdus merula*	Redwing	*Turdus iliacus*	Song Thrush	*Turdus philomelos*
Bearded Tit	*Panurus biarmicus*	Long-tailed tit	*Aegithalos caudatus*	Penduline Tit	*Remez pendulinus*
Eurasian blue tit	*Parus caeruleus*	Great Tit	*Parus major*	Treecreepers	*Certhia familiaris*
House Sparrow	*Passer domesticus*	Indian Sparrow	*Passer domesticus indicus*	Tree Sparrow	*Passer montanus*
Rock Sparrow	*Petronia petronia*	Chaffinch	*Fringilla coelebs*	Brambling	*Fringilla montifringilla*
Eurasian siskin	*Spinus spinus*	Common Rosefinch	*Carpodacus erythrinus*	Desert finch	*Rhodospiza obsoleta*
Bullfinch	*Pyrrhula pyrrhula*	Yellowhammer	*Emberiza citrinella*	Reed Bunting	*Emberiza schoeniclus*
Ortolan Bunting	*Emberiza hortulana*	Red-Headed Bunting	*Emberiza bruniceps*	Snow Bunting	*Plectrophenax nivalis*

Note: *species included in Kazakhstan's Red Book are marked in bold and **