CaspECO Project

Review of the status of invasive species, with special focus on the most invasive species

Mnemiopsis leidyi (A.Agassiz, 1865) and their effects on the Caspian ecosystem.

Synthesis of the national reports of Azerbaijan, Iran, Kazakhstan, the Russian Federation and Turkmenistan on invasive species, published sources and own data

Review by
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Regional consulter on invasive species to the CaspECO

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EXECUTIVE SUMMARY

Introduction

The main focus of review:

To determine the Status of invasive species with special attention to the most aggressive invader *Mnemiopsis leidyi* in the Caspian Sea
Objectives:
1. To assess vectors, pathways of invasive species introduction, their composition and their role in the Caspian ecosystem.
2. To analyze seasonal and interannual dynamics of the *Mnemiopsis leidyi* population in the all areas of the Caspian Sea; its impacts on the Caspian ecosystem including food recourses (zooplankton) and fish stocks along with other emerging environmental threats such as increased nutrient load from the coast, structural and quantitative changes in phyto-and-zooplankton communities, the appearance of harmful algal bloom (HAB) in the Southern Caspian.
3. To prepare recommendations for follow-up actions on invasive species management:
- for the protection and control of the Caspian Sea from any sources of accidental invasive species introductions
- for possibility of biological control of invader *Mnemiopsis leidyi*.

The primary source of this Review has been national reports from every of the five Caspian littoral countries, which included results of national observations of ecosystem state and biodiversity of the Caspian Sea. But due to fragmental data of the national observations on invasive species and especially on *M.leidyi* in the most of reports, in addition own author's data and recent published sources have been used for completing report.

General background

The Caspian Sea Environment Programme (CEP) previously and CaspECO Project now noted that the impacts of invasive alien species within the Caspian Sea currently pose a serious threat to its environment, and has consequently identified the invasive species problem as one of its priority areas. During its first phase, the CEP's efforts focused on developing knowledge and scientific information relating to the most critical current invasive species with special attention to *Mnemiopsis leidyi* after it invasion into the Caspian Sea. In its second phase, the CEP paid special attention to legal and legislative elements of the invasive species, specifically in relation to

- implementation of the Strategic Action Program (SAP) for the Caspian, and
- strengthening environmental legislation and policy frameworks operating at regional and national levels (including implementation and compliance.)

As a basis for this work, the CEP has noted that "a significant number of alien plant and animal species have also been introduced into the Caspian Sea, some - intentionally and others – accidentally. These introductions have been made without consideration being given for protection of the Caspian ecosystem, of its native biota, or to ensuring that impacts and consequences of introductions are assessed and minimized." In absolute terms, the number of different species introduced in this way may be thought relatively low, however, enclosed seas are known to be extremely susceptible to harm from invasive species, due to high levels of endemism, isolation and the unavailability of other external protections.

As it was mentioned during the first phase of the Caspian Environment Programme (CEP), particular attention was paid to the ctenophore species, *Mnemiopsis leidyi*, which was introduced into the Caspian in 1999. After introduction of ctenophore *Mnemiopsis leidyi* into the Caspian Sea CEP addressed its activity on the creation regional invasive species advisory group of the experts and the first meeting of the CEP (December 2001) was organized where international and national experts were invited for development an action plan that has been adopted to counter the invasion of the Caspian Sea by the carnivorous comb jelly *Mnemiopsis leidyi* , which had caused serious symptoms of degradation in the food web of the Sea. Then workshop “ Aquatic invasions in the Black, Caspian, and Mediterranean seas” (Co-directors Henri Dumont and Tamara Shiganova) was held in Baku on June 25-26 2002, where also problem of invasive species and *Mnemiopsis leidyi* in particularly were discussed and possible measures to control *M. leidyi* population were formulized. During the second meeting of the CEP Regional Invasive species Advisory Group followed this workshop at the CEP PCU on 27 June 2002 the following objectives as action plan were accepted:

- To review any changes and developments in the situation of *Mnemiopsis* in the Caspian Sea as had occurred since spring 2002.
- To take note of the results of a NATO ARW workshop on *Mnemiopsis* and other invasive species hold in Baku on June 25-26, 2002.
- To review and actualise the Action plan and analyse progress made in the implementation thereof.
- To identify remaining gaps in our knowledge about *Beroe ovata (*predator of *M.leidyi)*, in particular those that might provide an in impediment to introduction.
- To discuss the outline of the EIA required by FAO and the Caspian countries as a condition to an introduction of *Beroe ovata*.

Among the various efforts to address this invasive species, the Caspian countries are considering the introduction of “biological controls” in the form of other non-native species, such as another ctenophore species*, Beroe ovata,* which is specialized predator on *M. leidyi* and directly prey on all stages of *Mnemiopsis leidyi*. Dr. Shiganova Tamara was requested to write Environmental impact assessment (EIA) for *Beroe ovata* introduction, which was written in 2002 and edited by Henri Dumont (Shiganova, 2002). Experiments on introduction *Beroe ovata* were performed with support of CEP in Iran, with support of national organizations in Turkey and Russia (SIO RAN, CaspNIRKH) in several locations. Experiments proved that *Beroe ovata* can live and consumes *M.leidyi* at salinity not less than 7,3 ‰, reproduce at salinity not less than 10‰. Thus Beroe *ovata* might be introduced in the Southern and Middle Caspian – the main areas of *M. leidyi* occurrence. But final decision was not accepted due to different opinions of responsible governmental representatives and measures to combat aggressive invader were not implemented.

Several years later in 2007 report “Review of National Legislation on Introduction of Alien Species” **(**Tomme Rosanne Young, 2007) was written. Report has been focused mainly on law and legislation, relating to the invasive species problem, intentionally avoiding detailed discussions of the science and social science of invasive species. Consequently, this report has been based on certain unavoidable principles:

- First, invasive species science remains uncertain. "Predictive models" are currently not dependable in their efforts to predetermine whether or not a species will be "invasive" in a particular ecosystem.
- Second, many critical national activities and industries (including agriculture, forests, and fisheries) depend on the intentional introduction of non-native species. Others, especially in the transportation industry, may cause unintentional introductions.

Taken together, these principles author lead to the conclusion that it would not be possible to simply forbid the introduction of invasive species. Rather a balanced system must be developed that will maximise the country's ability to identify and avoid invasiveness problems at the earliest possible stage, without crippling critical industries that depend on non-native species, and without placing various governmental agencies in conflict with one another. In this process, author addressed several kinds of actions –

- to impose restrictions and oversight of intentional species introductions,
- to attempt to control and/or prevent unintentional introductions, and
- to enable governmental officials to monitor and oversee ecosystems and take action when species invasions are discovered.

Thus during last years all previous reports including Biodiversity project (III.2005-IV.2006) have avoided detailed discussions of invasive species properly and their role in the Caspian ecosystem based on the scientific data, which may determine the real impact on ecosystem from their introductions. But without knowledge all invasive species, their origin, vectors and pathways of introduction, their biology, role in community occupied and impact on biodiversity and total ecosystem impossible to create action plan adapted for the Caspian region and for the Caspian invasive species depletion and prevention of new introductions.

Therefore it is hoped that this analysis will provide a fresh viewpoint at invasive species status, clarify their origin in the Caspian Sea and then will concentrate on the current population state and role of *Mnemiopsis leidyi* in decline in biodiversity and in bioresources (fisheries) in the Caspian region.

The objectives of the report have been identified as follows :
1. To review the Status of invasive species – *Mnemiopsis leidyi* in the Caspian Sea,
2. To assess vectors, pathways, and composition of non-native species, their role in the Caspian ecosystem
3. To review and assess, spatial, temporal, seasonal distribution, reproductive biology and physiological features of *M.leidyi* in the Caspian Sea
4. To review and assess the impact of *M.leidyi* on pelagic and benthic communities and the consequences for Caspian fisheries and Caspian Seal
4. To prepare Recommendations for follow-up actions on invasive species management and possibility of biological control of invader *M. leidyi*.

The primary source of this Review has been national reports from every of the five Caspian littoral countries, which included results of national observations of ecosystem state and biodiversity of the Caspian Sea. But due to fragmental data of national observations on invasive species and especially *M.leidyi* in the most of reports, own author's data and published sources have been used for completing report.

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OTHER RELEVANT DOCUMENTS (Separately Provided)

Azerbaijan – National Legislative Report
Iran – National Legislative Report
Kazakhstan – National Legislative Report
Russian Federation – National Legislative Report
Turkmenistan – National Legislative Report

List of Acronyms and Short Names

Biocontrol Code	Code of Conduct for the Import and Release of Exotic Biological Control Agents
BWC	The 2005 IMO Ballast Water Convention
Cartagena Protocol	The Cartagena Protocol to the CBD
CBD	Convention on Biological Diversity
CBD Principles	The CBD Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species
CCRF	Code of Conduct for Responsible Fisheries
CEP	(UNEP) Caspian Sea Environmental Programme
CHM	Clearinghouse Mechanism of the CBD
CMS	Convention on Migratory Species
EIA	Environment Impact Assessment
FAO	UN Food and Agriculture Organisation
GISP	Global Invasive Species Programme
Globallast	Global ballast water management program
GMO	Genetically Modified Organism (sometimes also called “LMO”)
IPPC	International Plant Protection Agreement
ISSG	IUCN Invasive Species Specialist Group

LMO	Living Modified Organism (also called GMO)
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships
OIÉ	World Organisation for Animal Health (formerly the "*Office International des Épizooties*")
PBBS	Port Biological Baseline Surveys
RAG	Regional Advisory Groups (Tehran Convention)
SAP	Strategic Action Plan for the Caspian
SPS Agreement	Agreement on Sanitary and Phytosanitary Measures
TBT Agreement	Agreement on Technical Barriers to Trade
Tehran Convention	Framework Convention for the Protection of the Marine Environment of the Caspian Sea
TOR	Terms of Reference
UNCLOS	UN Convention on the Law of the Sea
WTO Agreement	Agreement Establishing the World Trade Organisation

Review and Synthesis:

The status of invasive species introduction with special a focus on the most invasive species *Mnemiopsis leidyi* and its effects on ecosystem.

1. Background

CaspECO Project builds upon a solid foundation of regional cooperation for Caspian environmental conservation put in place by the five Caspian states and the Caspian Environmental Program over the period of more that 10 years with substantial catalytic support from the Global Environmental Facility (GEF). Building on these achievements this project's objective to strengthen regional environmental governance and apply new thinking to the sustainable management and conservation of the Caspian bioresources.

The project supports the littoral states' efforts to half the decline of bioresources and restore the depleted fisheries in the Caspian Sea, though the implementation of agreed actions defined in the Caspian Strategic Action Plan (SAP), and to fully operationalize and make the Caspian Sea's regional environmental governance mechanism sustainable.

In line with the new GEF priorities, the major focus of GEF will be to assist the counties to agree on the political commitments made to ecosystem based joint action on sustainable fisheries and bioresourses and introduce institutions and reforms to catalyze implementations of policies reducing over-fishing and benefiting communities. There are two components of the project: 1) ecosystem based management of aquatic bioresourses and 2) strengthened environmental governance.

This activity is planned to be implemented under the component 1, Output 4 and 5 of the CASPECO project document: Recommendation for regional management of ballast water to control invasive species traffic among the Caspian and the Black seas and Regional collaborative process focusing on *Mnemiopsis leidyi* control. Furthermore, based on recommendations of the CASPECO Steering Committee meeting held in Almaty on 14 September 2010, PMCU has been tasked to prepare a report on the status of invasive species – *Mnemiopsis leidyi.*

Work under this output follow up on *Mnemiopsis* related work done under CEP/GEF I and II. Follow-up is needed to catalyze more regional cooperation on the basis of the biodiversity Protocol to the Tehran convention. Work under this output will seek to catalyze discussion and actions at the national and Caspian national level.

1.1 Terms of Reference

To do this, regional Consultant has been recruited to build upon CEP/GEF II recommendations for invasive species management and possibility of biological control of *Mnemiopsis*. Based upon an analyses monitoring data from national monitoring surveys recommendations have been formulated and specific actions points have been developed for inclusion into TC program of work, approval by the COP, and incorporation into each country's respective National Strategic Convention Action Plan (NSCAP).

1.2 Purpose and Score of Assignment

Under the Terms of Reference for this assignment the Regional Consultant will undertake the following tasks:

1) Develop regional report on the status of invasive species – Mnemiopsis leidyi in the Caspian Sea based on the results on the countries baseline reports prepared by the members of the Working Group on Ecosystem Based Bioresources Management (EBM). These countries based reports include on the section on the state and dynamics of the main biological populations (as related to bioresouirces) namely: long term dynamics and spatial distribution of biomass of zoo-, phytoplankton, phytobenthos, zoobenthos and *Mnemiopsis leidyi*.

In addition to the Country Baseline Reports, the following sources of information and data are to be referred (but not limited to) previous reports and publications on invasive species and *Mnemiopsis leidyi*, national monitoring reports on *Mnemiopsis leidyi*; reports prepared by the Invasive Species Advisory Group established under the auspices of the CEP II, Transboundary Diagnostic Analysis Report (TDA-2002) and in particularly Updated TDA-2007.

1.3 Methodology and Inputs

As its primary mandate, this Summary Report is intended to synthesize and analyze the state of invasive-species with the focus on *Mnemiopsis leidyi* in the five Caspian countries. It is based on legal studies prepared for the CaspEco national consultants in each country, as listed below. The Terms of Reference for these National Consultants were designed to ensure that each National Consultant either (1) was already expert in the legal issues of invasive species within his country, or (2) would develop the primary knowledge needed in the course of completion of the work. In either case, it is hoped that the National Consultants will serve as continuing experts for purposes of this project.

These national reports were provided by national Consultants of the Caspian littoral countries listed below:

Country	**National Consultant**
Republic of Azerbaijan	Prof. M. M. Akhuntov
Islamic Republic of Iran	R. Shahifar
Kazakhstan	K. Isbekov
Russian Federation	B. Morozov
Turkmenistan	D. Annycharyeva

The primary source of this Report have been national reports from each of the Caspian littoral countries which included results of national observations of biodiversity and invasive species with the special focus on the invasive ctenophore *Mnemiopsis leidyi* of the Caspian Sea. But due to fragmental data of the national observations on the invasive species and especially on *M.leidyi* in the most of reports, own author's data and recent published sources have been used for completing "Review and Synthesis".

1.4 Terminology.

Until quite recently, that diversity reflected the historical evolution of each given region and was characterized by a number of species and sometimes higher taxa that were products of local evolution and were therefore endemic to the basin in which they had originated.

In the second half of the 20th century, a sharp increase in the number of non-native animal and plant species in any ecosystem, terrestrial and aquatic alike, occurred. In marine systems, they appeared in pelagic and benthic communities. Like an infection, this process rapidly spread globally. Currently, the “spontaneous” appearance of invasive, non-native species in various taxonomic groups from algae and protists to fishes, and their establishment in the new biotopes has become a priority concern for coastal regions of the World Ocean, inland seas, as well as for brackish and freshwater basins.

The appearance of new species in aquatic ecosystems, referred to under a variety of names as non-native species, invaders, exotics, or non-indigenous species (NIS), may be the result of to a spontaneous penetration via straits and rivers (natural range expansion) or, most frequently, of human activity. Humans, intentionally or occasionally, may favor the introduction of a new aquatic species to a given basin. According to the International Convention on Biological Diversity (CBD), the following terms are now widely accepted:

-the region from which the species is supplied is referred to as the native or the **donor area;**

-the region to which the object is transferred is referred to as the **recipient area**;

-the modes of the invasion of non-native species are referred to as the **vectors**; among them, natural and anthropogenic vectors are distinguished;

-the routes along which spontaneous invasion of non-native species occurs are referred to as **invasion pathways**. If species penetration via these pathways is repeated or systematic, they are named **invasive corridors** (Carlton, 1996).

The species that appear in a recipient region and produce an independent reproductive population here should be regarded as established non-native (briefly, non-native) species. The term **invader** is applied to a species that exerts a negative effect on other species or the entire ecosystem of the recipient basin.

To refer to a species whose origin is uncertain, the term “**cryptogenic**” is used. Commonly, these species include cosmopolitan species, which are universally spread and of which it is difficult to ascertain the initial region of origin.

The following most widely spread root causes of the appearance of non-native species were taken into consideration:

Natural expansion. The presence of a given species in a given new location is the result of a natural penetration, mainly via existing, natural waterways. This mode of expansion recently became more prominent owing to global warming, giving thermophilic species a chance to extend northward. Due to the slow but steady temperature increase, environmental conditions there had become sufficiently favorable to host their populations on a permanent basis.

Aquariumistics. Aquarium animals and plants often travel huge distances from their natural origin to their final destination. There are often few or no restrictions, and a lack of enforcement of such, on their trade, and their owners may occasionally dispose of them while still alive or viable, or allow them to escape in an environment that is essentially alien to them. In the 20th century, aquarium trade became so widely spread that it acquired an industrial character.

Aquaculture. For a long time marine and freshwater aquaculture consisting of the intentional introduction and breeding of new commercial species in ponds, lagoons, bights, and near-shore regions, either free or in suspended cages, have been a major vector of invasive taxa.

Intentional introduction of commercially valuable species: many animal species, mainly crustaceans and fish, have been intentionally introduced to new aquatic environments in order to create an additional food resource there.

Accompanied releases: along with a species destined for intentional release, undesirable animal and plant species may occasionally be introduced; among them, in selected cases, even parasites can be released, become established, and change host afterwards, potentially or in the facts causing major damage to the new host.

Construction of canals and reservoirs. A formidable vector that opens up new highways to the penetration of non-native species into new basins, fully related to unintentional human intervention, is the construction of canals, connecting previously isolated seas, lakes, and rivers. Through them, species from one basin may find an easy boulevard to penetrate to others, either in a natural way, or attached to or inside of ships. A most prominent example was caused by the construction of the Volga–Don Canal. Soon after it opened, species from the Black Sea and the Sea of Azov, together with invaders that had previously acclimated to these seas, started to penetrate the Caspian Sea. Some of these invaders went further, taking advantage of the Volga–Baltic system to end up in the Baltic and White seas. Thus, the so-called ***northern*** invasive corridor for aquatic Ponto–Caspian species appeared (Panov et al. 1999; Panov et al., 2007), first of all, Ponto–Caspian animal species from their previously closed basin the ***central corridor*** was thereby created. From there, selected species were transported by ships across the Atlantic, establishing themselves in the Great Lakes of North America (Jazdzewski, 2002; Mills et al., 1993).

2. Chronology of invasive species introductions

2.1 Ponto-Caspian basin and biota origin

The Black, Azov, and Caspian seas (Ponto-Caspian) were united as a single basin several times in the past, most recently in the Pliocene, when they were connected in the almost freshwater Pontian Lake–Sea. The marine biota was eliminated and a brackish-water biota then formed. Its representatives still dwell in the Caspian Sea, the Sea of Azov, and in desalinated regions of the north-western Black Sea; these are referred to as Pontian-Caspian species. The Black and Azov seas were reconnected again with Caspian Sea by the Volga–Don Canal in 1952. The Black Sea is also a part of the Mediterranean basin and is connected via the Bosporus Strait with the Sea of Marmara and further by the Dardanelles Strait with the Mediterranean Sea. Owing to accelerating human activities such as shipping, deliberate stocking, unintentional releases, and canal constructions, many non-native species have arrived and established in the Black Sea and spread further to the Sea of Azov and the Caspian Sea. After the construction of ballast water tanks in ships this process became global.

2.2. The Caspian Sea Environment, Native Biota, Disturbance

The Caspian Sea is the largest inland water body with no connection with the World Ocean; its shelf zone (< 100 m depth) occupies 62% of its surface area. Physical geography and bottom topography divide the Caspian into Northern, Middle, and Southern regions. The crucial element of its water balance is the relation between the supplied and expended water. Changes in the intensity of the water delivery cause sea level oscillations. Sea-level oscillation is one of the main factors that determine the status of its ecosystems. During the 20th century, environmental conditions deteriorated significantly, mainly owing to sea-level changes, river runoff regulations, and pollution from multiple sources including petroleum hydrocarbons and phenols (Kosarev, 2006).

The sea is situated in different climatic zones subjected to the influence of cold Arctic masses in the north, dry continental masses driven from Kazakhstan, and warm tropical masses arriving from the Mediterranean Sea and Iran. This results in great increments in the temperature distribution in the surface layer. The temperature differences between different regions of the Caspian Sea are especially manifested in the wintertime, when the temperature changes from 0–0.5°C near the ice edge in the North Caspian (which is covered with ice in the winter) to 9–11°C in the south. In the summer months, the mean monthly temperatures in the surface layer in the northern and middle parts of the sea are 24–26 ºC; the corresponding values for the southern and southeastern parts are 25–26°C and 27– 30°C, respectively. The maximal water temperatures are observed in August. At the end of May–beginning of June, a thermocline layer starts forming in the open regions of the sea; it is best expressed in August. Usually, it is located at a depth of 20–30 m in the Middle Caspian and at a depth of 30–40 m in the South Caspian. In the autumn, with the temperature decrease, the thermocline destroys and absolutely vanishes by the end of November (Kosarev, 2006).

The sharpest changes in the water salinity are observed in the North Caspian: from 0.1‰ in the near-mouth areas of the Volga and Ural rivers to 10–11‰ at the boundary with the Middle Caspian. In the Middle and South Caspian, salinity variations are small ranging from 12.6 to 13‰. The salinity slightly grows with depth by 0.1–0.2‰.

The changes related to the sea level oscillations are mainly manifested in the North Caspian, where they affect the depth and structure of the zone of interface between the Volga and Caspian waters and the chemical composition of the waters. Meanwhile, in the Middle and South Caspian, where the total water volume is significantly greater than the volume of the riverine runoff, the changes are minimal (Kosarev, 2006).

Inhabitants belong to four groups. The most ancient and abundant are autochthonous (Ponto-Caspian) species (84%). Arctic species (3%) arrived during the last glaciations. Atlantic-Mediterranean species (1%) penetrated about 13,000 years ago. They have become full members of

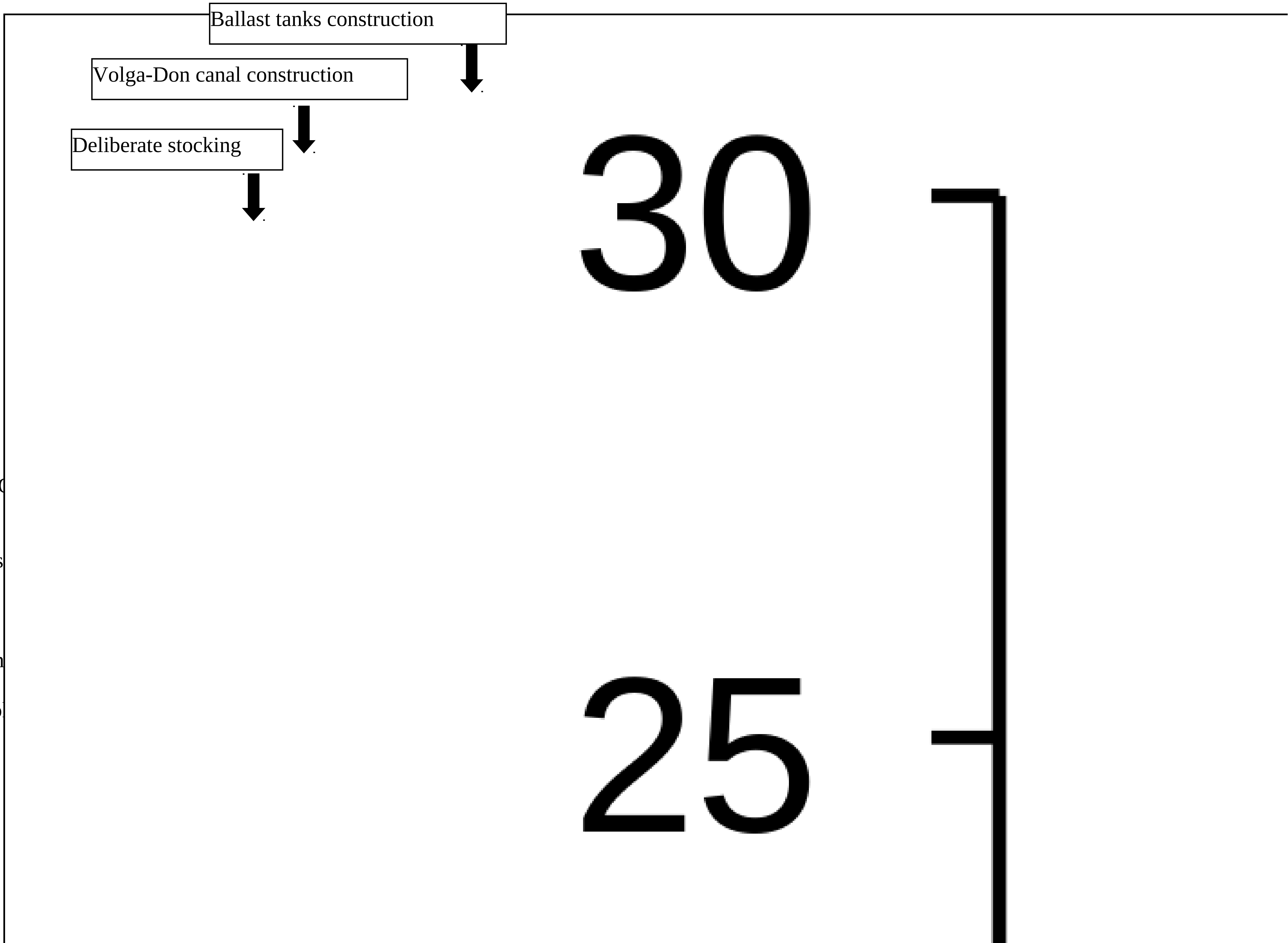
Caspian communities, have evolved considerably, and have generated new species and subspecies. Freshwater species (13%) have entered on several occasions (Zenkevich, 1963).

The present-day Caspian Sea is relatively species-poor. Species richness is lower than that of the Black Sea by a factor of 2.5, although the biota contains 733 species and subspecies of plants and 1814 species and subspecies of animals, of which 1069 are free-living invertebrates, 325 are parasites, and 415 are vertebrates (the latter are mainly represented by freshwater species; this list is still growing). The principal causes of the high degree of faunal endemism lies in the long-term isolation of the basin and its salinity regime. The low salinity (0.1–11% in the Northern Caspian, 12.6–13% in the other parts) and its native biota restricted colonization by many marine species and, at the same time, constrained access by freshwater species. In spite of low biodiversity, the Caspian Sea has high productivity, particularly in the Northern Caspian, and rich fish stocks (Kasymov, 1987).

2.3. Vectors, pathways, and composition of non-native species.

The appearance of non-native species and changes in native biodiversity may be divided into three phases (Figs. 1 and 2) with some exclusions.

The most pronounced exclusion was introduction of bivalve *Mytilaster lineatus* (Gmelin, 1791), which appeared in the Caspian Sea in the fouling of the bottoms of small vessels was brought from the Black Sea in 1919 in Baku harbour (Bogachev, 1928).



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inadvertently released with them, and became a valuable food source for benthic-feeding fishes. Eight rough fish and fish parasites were also inadvertently introduced during these actions (Karpevich 1975; Shiganova, 2009). One more species diatom *Pseudosolenia* (= *Rhizosolenia) calcar-avis)* was introduced accidentally during deliberate introduction of grey mullets (Usachev, 1947). Its impetuous development and unusually rapid distribution by the Caspian Sea water area led to the replacement of another diatom of the same genus *R. fragilissima* and press of dinoflagellate algae *Prorocentrum cordatum* (= *Exuviaella cordata)* on the major part of the water area that were referred to the dominating species before *P. calcar-avis* appearance. Phytoplankton biomass increased as a result about half as much again. *P. calcar-avis* makes up 80-92% of the total phytoplankton biomass in the Middle and Southern Caspian in some seasons. *P. calcar-avis*, a large size alga, can not be used as food by the Caspian zooplankton organisms, and after elimination the synthesized organic matter sinks down to the bottom, where it is processed by bacteria and is included into the benthic food web, that is why, its introduction caused a serious rearrangement of energy fluxes in the Caspian Sea ecosystem (**(**Levshakova and Sanina, 1973**;** Ardab’eva et al., 2000).

The second introduction phase started when the Volga-Don Canal opened in 1952 (Fig.1). First most of the species were carried from the Black Sea by ships as fouling organisms. Among them zoobenthic animals and macrophytes were dominated. Two species of barnacles *Balanus improvisus* occurred in largest and *B. eburneus*, first were discovered in the Caspian Sea in 1955 and 1956 (Derzhavin, 1956). After barnacles followed bryozoans *Conopeum seurati*, *Electra crustulenta* (Apricots, 1959), *Lophopodella carteri* (Apricots, Kosovo, 1963), fouling hydromedusa *Bougainvillia megas* (Kinne), Kamptozoa *Barentsia benedeni* (Foetinger 1887) (Zevina, 1968), polychaete *Mercierella (Ficopomatus) enigmatica.*

M. enigmatica rapidly established and began to reproduce in the Krasnovodsky bay in 1958-1961. Its biomass (together with limestone house) reached 30 kg/m^2 (Bogoroditsky, 1963). However, later it was noted in the samples was extremely rare (Karpinsky, 2002). Then in the Caspian Sea penetrated bivalve mollusks *Hypanis (=Monodacna) colorata* (Saenkova, 1960), amphipods *Corophium volutator* (Pallas 1766) (Birshtein, 1968), *Gammarus aequicauda* (Martyinov 1931) *Iphigenella shablensis* (Carausu, 1943) (Grigorovich et al., 2002)**,** and the pearlwort *Conopeum seurati* (Canu) *(=Membranipora crustulenta*) (Karpinsky et al., 2006)

In 1971, in the Volga delta brackish water gastropod mollusk *Lithogliphus naticoides* Pfeiffer had appeared, intermediate host of several types of parasitic trematodes, who had followed him (Karpinsky et al., 2006). A relatively recent benthic colonizer in the Caspian Sea became a mollusk *Dreissena bugensis* Andrusov 1897, discovered in the Northern Caspian, and appeared before this in the Volga River (Orlova et al., 1999). In the Southern Caspian was found nudibranch mollusk *Tenellia adspersa* Nordmann (Antsulevich and Starobogatov, 1990).

Probably in the fouling communities of ships hydromedusae *Blackfordia virginica* и *Moerisia maeotica* (Ostroumov) were brought from the Black Sea and first recorded in 1956 and 1960 respectively in the Caspian Sea. Earlier *Blackfordia virginica* was brought into the Black Sea from estuaries of the Northern America. *Moerisia maeotica* is a Ponto-Caspian species, occurs in the brackish waters of the northwestern Black Sea (Naumov, 1968; Logvinenko, 1959).

The only predator crab *Rhithropanopeus harrisii* (Gould) was introduced with ship fouling in the Caspian Sea. It was brought from the Atlantic coast of North America into the Black Sea then into the Caspian Sea, where it was discovered in 1958. Crab fairly quickly was spread through the water area of Northern Caspian Sea, and beyond to the sea (Reznchenko, 1967).

Among macropytes were found in late 1950s: the green algae *Acrochaete parasitica* Oltm, *Ectochaete leptochaete* Huber *(=Entocladia leptochaete)*, *Enteromorpha flexuosa* (Wulf) (=*E. tubulosa)*, *E. maeotica* Proshkina-Lavrenko, *Monostroma latissimum* (Kuetzing) Witt*;* the brown algae *Ectocarpus confervoides* var. *siliculosus* (Dillwyn) Farlow, *Entonema oligosporum* Stromfelt *(=Streblonema oligosporum);* and the red algae *Acrochaetium daviesii* (Dillw) Nag,, *Ceramium diaphanum* (Lightf) Roth, *Polysiphonia variegata* (C.Ag.)Zanard) *(=P.denudata)* (Zevina, 1994).

The third phase began in the early 1980s after ballast tanks constructions at the ships when mainly phyto- and zooplanktonic species began to arrive in ballast water (Fig.1). Among non-native phytoplankton species *Pseudo-nitzschia seriata* (Cleve) has become abundant, while *Pseudo-nitzschia pseudodelicatissima* (Hasle), *Chaetoceros pruvianus,* and the temporarily planktonic *Tropidoneis lepidoptera* (Greg. Cl.) have become widely distributed and are often recorded. In the Middle Caspian Sea the coccolithophore *Braarudosphaera bigelowii* (Gran & Braarud 1935) and globally significant coccolithophore alga *Emiliania huxleyi* (Lohmann) Hay & Mohler have been observed. *Emiliania huxleyi* has often "bloomed" in the Black Sea during the last several decades. In addition, two Black Sea dinoflagellate species were recently found in the Caspian Sea: *Gymnodinium sanguineum* Hirasaka (=*G.splendens* Lebour*)* and *Protoperidinium crassipes* (Kofoid) Ballech 1974 (Shiganova et al. 2005; Pautova et al. 2008).

Among zooplankton species also the Black Sea species and Black Sea invaders were recorded: Cladocera, *Podon intermedius* (Lilljeborg), Copepoda *Acartia tonsa* (Dana, 1849) (Kurasheva et al., 1992). Earlier *Pleopis polyphemoides* Leukart was introduced (Mordukhai-Boltovskoy, 1962).

In 1998 in the Southern and Middle Caspian fishermen recorded unknown gelatinous species. In 1999 on the boundary of the Middle and Southern Caspian individuals of ctenophore *Mnemiopsis leidyi* and medusa *Aurelia aurita* were found (Ivanov et al., 2000; Esmaeili et al, 2000; Shiganova et al., 2001ab). On the base of molecular analyses it was discovered that *Mnemiopsis leidyi* was brought from the Black Sea. And to the Black Sea it was brought from the Gulf of Mexico (Fig.2) (e.g., Florida, Tampa Bay) (Ghabooli, Shiganova et al., 2010). Subsequent to colonization of the Black Sea, invasion of the Sea of Azov would be relatively straightforward given the natural connection between these basins (Shiganova et al.

2001b). In addition, the Don-Volga canal, which links the Don River and the Sea of Azov to the Volga River and the Caspian Sea, allows commercial vessels to move between these basins. Discharge of contaminated ballast water from the Black/Azov Sea likely accounts for the invasion of the Caspian Sea (Shiganova et al. 2004b).

Populations of *M. leidyi* in the Black and Caspian Seas exhibited very similar allelic diversity, and the low F_{ST} value suggests high genetic affinity of these populations. Moreover, populations of the ctenophore collected from the northern and southern Caspian Sea – across which profound thermal and salinity gradients exist – also exhibited little population differentiation.

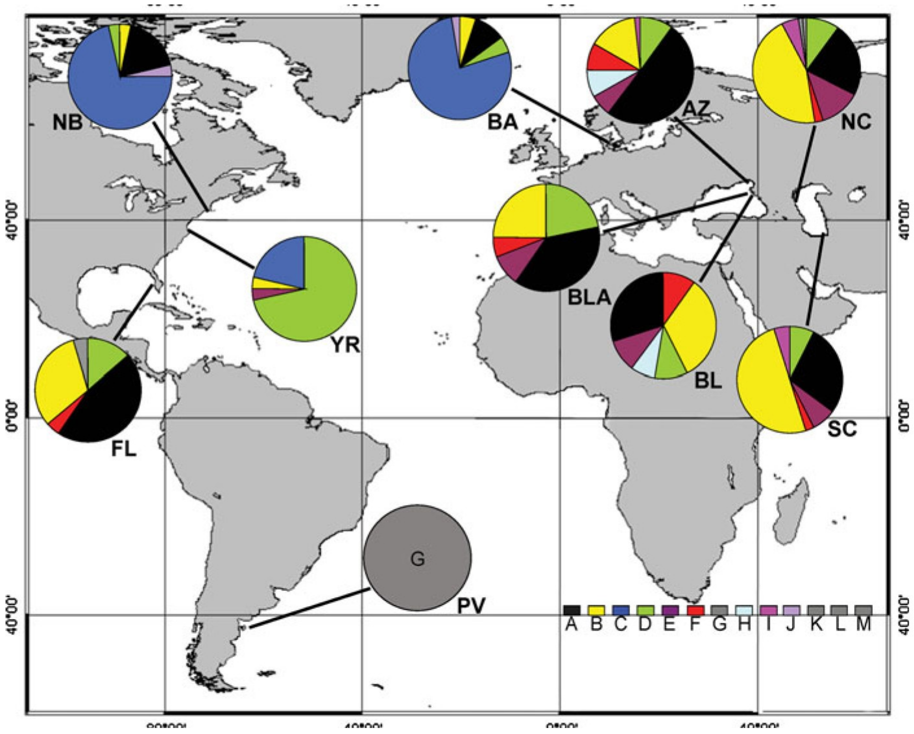

Fig. 2. Allele distribution map of *M. leidyi*. Each colour indicates a different allele. Private alleles are highlighted in grey. Population codes are described in Table 1 (After Ghabooli et al., 2010)

Table 1 Alleles (A-M) found in the 10 surveyed *Mnemiopsis* populations and their polymorphic sites at the corresponding nucleotide position of the sequence (After Ghabooli et al., 2010).

	ITS2			ITS1				Populations										
Allele	64	193	212	416	507	574	583	AZ	BL	BLA	NC	SC	BA	FL	NB	YR	PV	
A	C	A	A	A	C	A	C	7.89	3.68	3.15	4.73	2.89	1.05	2.10	2.36			27.85
B	C	A	T	G	C	A	C	2.89	3.42	2.10	9.47	5.00	0.52	1.84	0.52	0.26		26.02
C	C	G	A	G	C	A	C						7.89		5.26	1.57		14.72
D	C	A	A	G	C	A	C	1.05	1.05	1.84	2.10	0.78	0.52	0.78	0.26	5.26		13.64
E	T	A	A	A	C	A	C	1.05	0.78	0.78	2.63					0.26		5.50
F	C	A	T	A	C	A	C	0.78	1.05	0.52	0.52	0.52		0.78				4.17
G	C	A	A	G	T	A	C										2.63	2.63
H	C	A	T	G	C	T	C	1.31	0.52									1.83
I	C	A	T	G	C	A	A	0.26			1.05	0.52						1.83
J	C	G	A	A	C	A	C						0.26		0.26			0.52
K	C	A	T	A	C	A	A							0.26				0.26
L	T	A	T	G	C	A	C				0.26							0.26
M	T	A	A	G	C	A	C				0.26							0.26

Mnemiopsis leidyi is widely distributed throughout of the Caspian Sea and reached the high abundance (Shiganova et al., 2001a; 2004ab, Kamakin et al., 2009).

Invasion by the Black Sea phyto- and zooplankton species is still going on. The copepod *Oithona silimis* Claus, 1866 has now been recorded for four years. *Penilia avirostris* Dana, whose invasion was doubted, was found in 2009 in the Middle Caspian (Shiganova, 2010).

All established non-native species were brought in these different periods mainly from the Black Sea and partly (intentionally introduced) from the Sea of Azov (Fig. 3). A first group includes 23 widely distributed and often abundant the euryhaline Black Sea species. They are of Atlantic-Mediterranean origin but have lived for 1,500--2,000 years in the Black Sea and adapted to its low salinity. They are Cladocera (*P. polyphemoides* Leukart, *P. avirostris*), *Podon intermedius* (Lilljeborg), the amphipod *Corophium volutator* (Pallas 1766), the bivalve *Mytilaster lineatus* (Gmel.), phytoplankton, and macrophytes. Another group consists of nine the Black Sea brackish water species that were adapted to life in low-salinity areas before invading similar areas of the Caspian Sea: the hydromedusa *Moerisia maeotica* (Ostroumov); amphipods *Gammarus aequicauda* (Martyinov 1931) and *Iphigenella shablensis* (Carausu); molluscs *Monodacna colorata* (Eichwald 1829) *Hypanis colorata)*, *Dreissena bugensis* Andrusov 1897, *Lithogliphus naticoides* Pfeiffer, and *Tenellia adspersa* (Nordmann 1845); kamptozoan *Barentsia benedeni* (Foetinger 1887); and pearlwort *Conopeum seurati* (Canu), *Electra (= Membranipora crustulenta*) (Karpinsky et al., 2006).

Fig.3.
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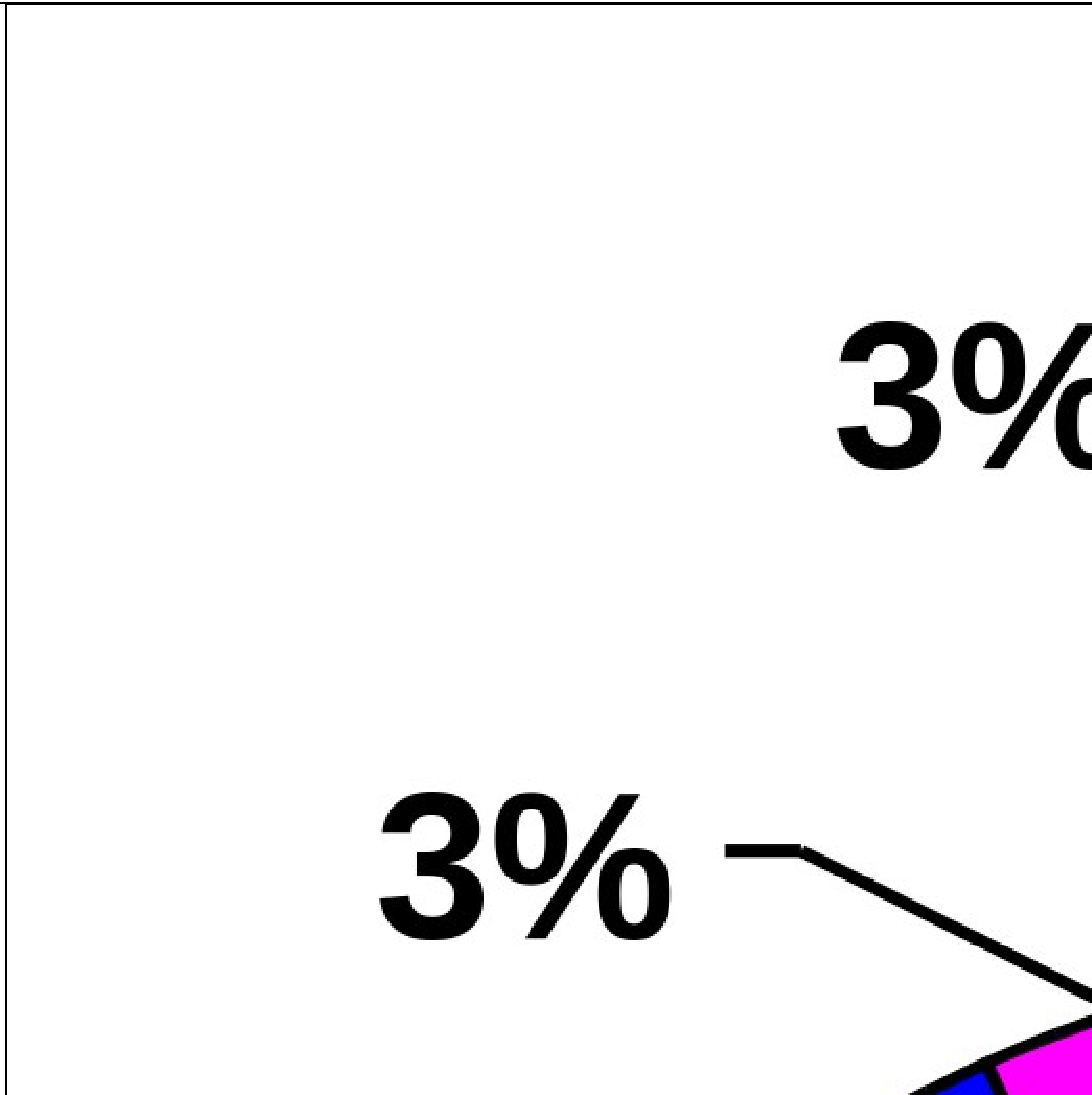


Table 2. List of the non-native species recorded in the Caspian Sea (in brackets species, which were recorded in the Caspian but it is uncertain if they established or not) (After Shiganova, 2010)

Taxon	Numbers of established species
Parasites of fishes	9
Phytoplankton	8 (+3)
Macrophytes	9
Kamptozoa	1
Scyphozoa	(1)
Hydrozoa	3
Ctenophora	1
Polychaeta	2
Copepoda	2 (+1)
Cladocera	3
Cirripedia	1 (+1)
Decapoda	4
Amphipoda	3
Bivalvia	4
Gastropoda	2
Bryozoa	3
Pisces	14 (+2)
Total	**60** (+6) without parasites

* in brackets species, which were recorded but non known if they established or not.

About 60 species are established, although some species are known only from single individuals; the persistence of eight more species is doubted, and four more species have only recently been found. Among them the scyphomedusa *Aurelia aurita* has been recorded only a few times in the Middle and Southern Caspian. The fate of *Balanus eburneus* is not known. Recently, seven more phytoplankton species and three zooplankton from the Black Sea were found in the Middle Caspian (Shiganova et al., 2005; Pautova, 2008), but it is not known if they have become established. Some introduced species also have failed to establish. Except for a few freshwater invertebrates and deliberately introduced freshwater fishes, plus two species deliberately introduced from the Sea of Azov, all established invaders were introduced from the Black Sea. Most established species are euryhaline; many are widely distributed in coastal waters and therefore have wide ecological tolerances. Fewer established invaders are from brackish water, and the only freshwater species are deliberately introduced fish. Among introduced species, there are more euryhaline species than in the native biota in both the brackish Northern Caspian and the Middle and Southern Caspian. Marine euryhaline non-native species have settled in the Middle and Southern Caspian, often replacing native species. Brackish and freshwater species have settled in the Northern Caspian, although the most euryhaline of them may penetrate into the Middle and Southern Caspian. Invasion rate accelerated during last decade due to the continuation of ballast water release (Fig.4) (Shiganova, 2010).

Fig.4. Cumulative graphs of non-native species invasion rate for 20-years intervals in the Caspian Sea in 1990-2010 (after Shiganova, 2010).

2.4. Ecosystem Impacts

The Caspian Sea ecosystem was the most vulnerable to invaders because of its long isolation and high level of endemism. Most Atlantic invaders had major impacts; for instance, *M. leidyi* affected all trophic levels and finally ecosystem functioning. Though few in number, these species occupy dominant community positions. They include the diatom *P. calcar-avis*, the cladoceran *P. polyphemoides*, and the copepod *A. tonsa*. The biomass of *M. lineatus, A. ovata, H.(N). diversicolor*, and *B. improvisus* makes up more than 60% of the total biomass of the benthos and fouled substrates. Fouling communities consist almost wholly of non-native species. Native species dominate only among the fishes(Shiganova, 2010) .

Overall, as a result of the invasion of benthic species there has occurred change of the trophic structure of the zoobenthos of the Caspian Sea. Some of the non-native species took the ecological (trophic) niche of native species, replacing them, being more adaptable and more successful competitors for food. Only *Abra abra* and *Hediste (Nereis) diversicolor*, new species that do not compete with the native Caspian species because they were intentionally introduced into the empty ecological niche deposit feeders living in the soil thickness. Since this ecological niche previously empty, they could use the large reserves of detritus on the surface of sediments (Zenkevtch, Birshtein, 1934).

Such benthic non-native species as *Mytilaster lineatus, Rhithropanopeus harrisii*, and especially deliberated *A. abra* and *H. diversicolor* began to play a significant role in the diet of fish, and especially sturgeons, and accounted for depending on the size of the sturgeon and areas from 11 to 72, 9% of the diet (Koncheva, 2004).

The mussel *M. lineatus,* which forms the bulk of the benthic biomass, replaced native species and is scarcely used by benthophagous fish and sturgeons. But during the last years after the invasion of *M.leidyi M. lineatus* has increasingly been found in stomach contents of benthophagous sturgeons owing to the absence of other available food (Molodtzova et al., 2004). The mullet fishery achieved only limited importance. The diatom *P. calcar-avis,* having increased phytoplankton biomass, was of limited nutritive value for zooplankters and pelagic phytophagous fish.

After the invasion of *M. leidyi,* the functioning of the Caspian ecosystem changed as in the Black and Azov seas previously (Shiganova et al. 2004ab).

3. Invasion of *Mnemiopsis leidyi* and its impact on the Caspian ecosystem

3.1. Spatial and temporal distribution of *M. leidyi* in the Caspian Sea.

Mnemiopsis leidyi has smaller size in the Caspian Sea (Fig.4). Average length of mature individuals is 15-30 mm. Maximal individual was found with a length of lobes 65 mm.

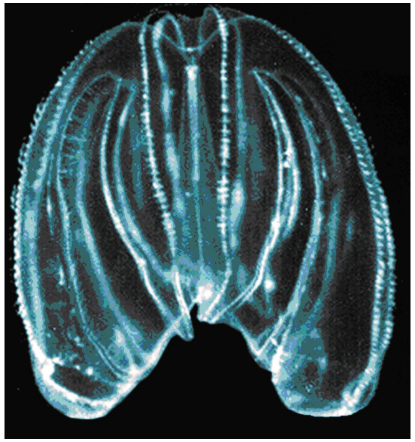


Fig.5. View of *Mnemiopsis leidyi* from the Caspian Sea
(Foto Shiganova T. and Kamakin A.)

As mentioned above ctenophore *Mnemiopsis leidyi* was first recorded in the Caspian Sea in November 1999, simultaneously with individuals of *Aurelia aurita* (Ivanov et al., 2000; Esmaeili et al., 2000). By summer 2000

M.leidyi started to reproduce and spread widely in the Southern and Middle Caspian (Shiganova et al., 2001). In October 2000 it was first discovered in the Northern Caspian, where its distribution was limited western part and isohaline 4.3‰. In 2001, a sharp increase its numbers was observed in the most areas of the Caspian Sea. It spread throughout the Southern and Middle Caspian in summer, and in August it entered the western and central parts of the Northern Caspian Sea up to the main bank. Its population multiplied, the number exceeded the highest values observed in the Black Sea during the peak period of development (mean 4590±4200 ind.m^{-2} (121±84 ind.m^{-3}) across the sea with maximum in the south-eastern area where abundance was 7800±1280 ind.m^{-2} (156±54 ind. m^{-3}), but biomass was lower because of much smaller size and weight individuals: 427±328 g.m^{-2} (18,5±19 g.m^{-3}) (all data without coefficient for insignificance of catchability) (Shiganova et al., 2004b) (Fig. 6).

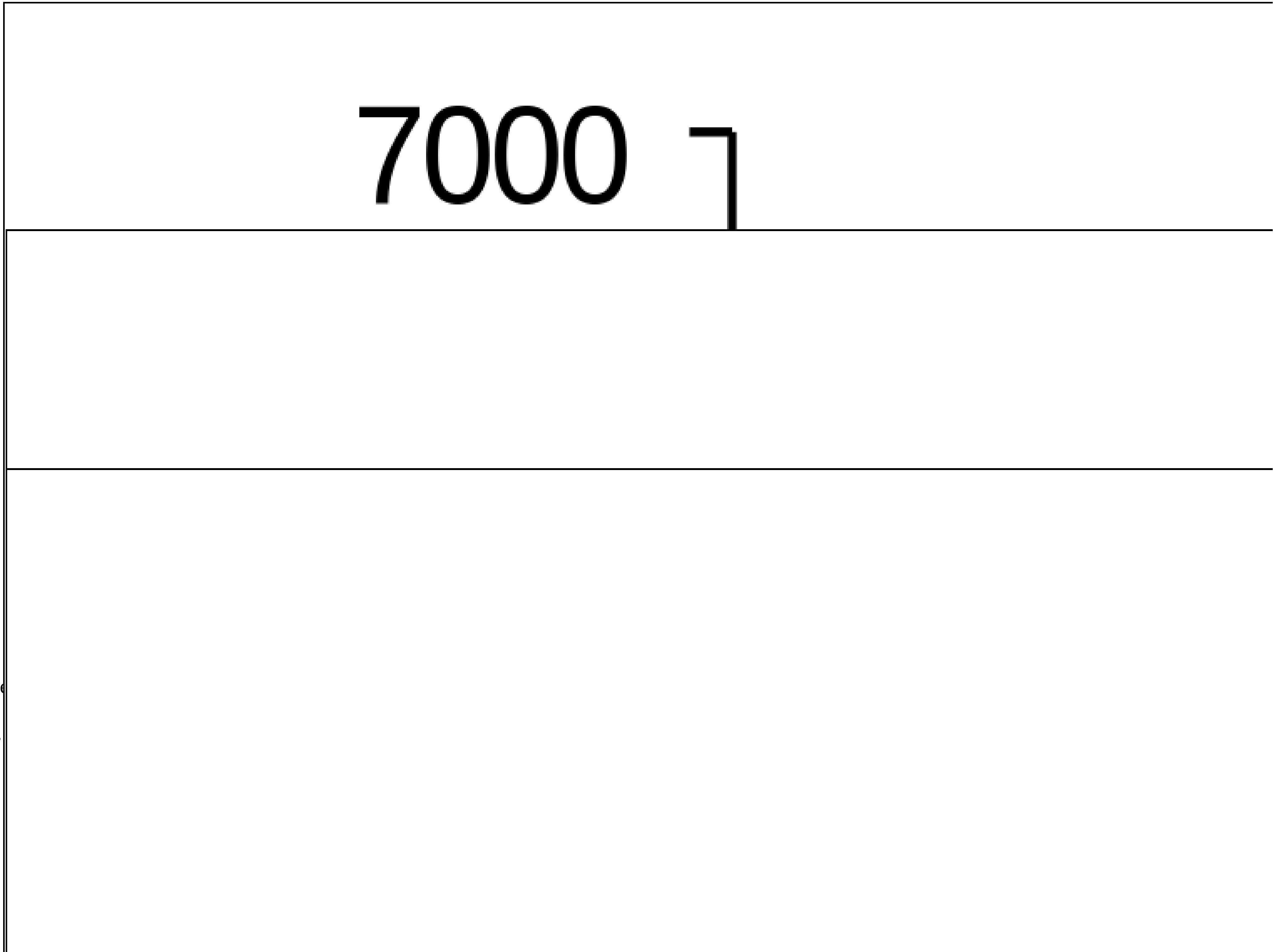
In 2002 г. its abundance increased even more reaching 5012±3200 ind.m^{-2} (177±350 ind.m^{-3}) in the Middle Caspian and 8085±613 ind.m^{-2} (262±126 ind.m^{-3}) in the Southern Caspian (Shiganova et al., 2001; Shiganova et al., 2004b). Values of *M.leidyi* abundance in 2002 were higher maximal abundance in the Black Sea (4600 ind.m^{-2} or approximately 2200 ind.m^{-2} without coefficient insignificance catchability) but lower then maximal abundance in the Sea of Azov which were recorded in August 1999: 21020 ind.m^{-2} (Mirsoyan et al., 2006) (Fig.6). In 2003 sharp decrease of *M.leidyi* abundance followed due to cold winter and spring around the entire Caspian, when temperature was lower more than 1- 2^0 C than in previous years. In south-eastern part temperature in February dropped to 5^0 C and *M.leidyi* was recorded only in warmer eastern part of the Southern Caspian. In other regions *M.leidyi* was not found in winter (Sokolsky and Kamakin, 2004). Its abundance remained low up to late August (Fig.6). Temperature of the upper layer in summer was 22-23^0C up to the middle August. In the Northern Caspian *M.leidyi* appeared only in the second part of August and its abundance was low 58 экз. $м^2$ (13 экз. $м^3$) (data of Shiganova T.). In late August temperature increased and *M.leidyi* could reach high abundance and it was even higher in September (Sokolsky and Kamakin, 2004). In 2004 during warm winter *M.leidyi* could reach the eastern part of the Northern

Caspian in February and it occurred there in April (Sokolsky and Kamakin, 2004, Shiganova et al., 2005). This was linked also to prevailed southern winds.

Analysis of the development of *M.leidyi* population in the Caspian Sea for 11 years has shown that interannual variation of *M.leidyi* numerical values depends on temperature, food concentration and direction of wind driving currents, which curry aggregations from the south to north (Shiganova, 2009).

Mnemiopsis leidyi reached pick of abundance in 2001 and 2002 as it is characteristic for a invader strategy first occupying new area. Then during following years its abundance varied depending on temperature, particularly crucial winter temperature and wind driving currents.

During last years *M. leidyi* increased abundance in the Middle Caspian and particularly in the Northern, the highest increase was recorded in August-September during its peak of development (Fig. 6).



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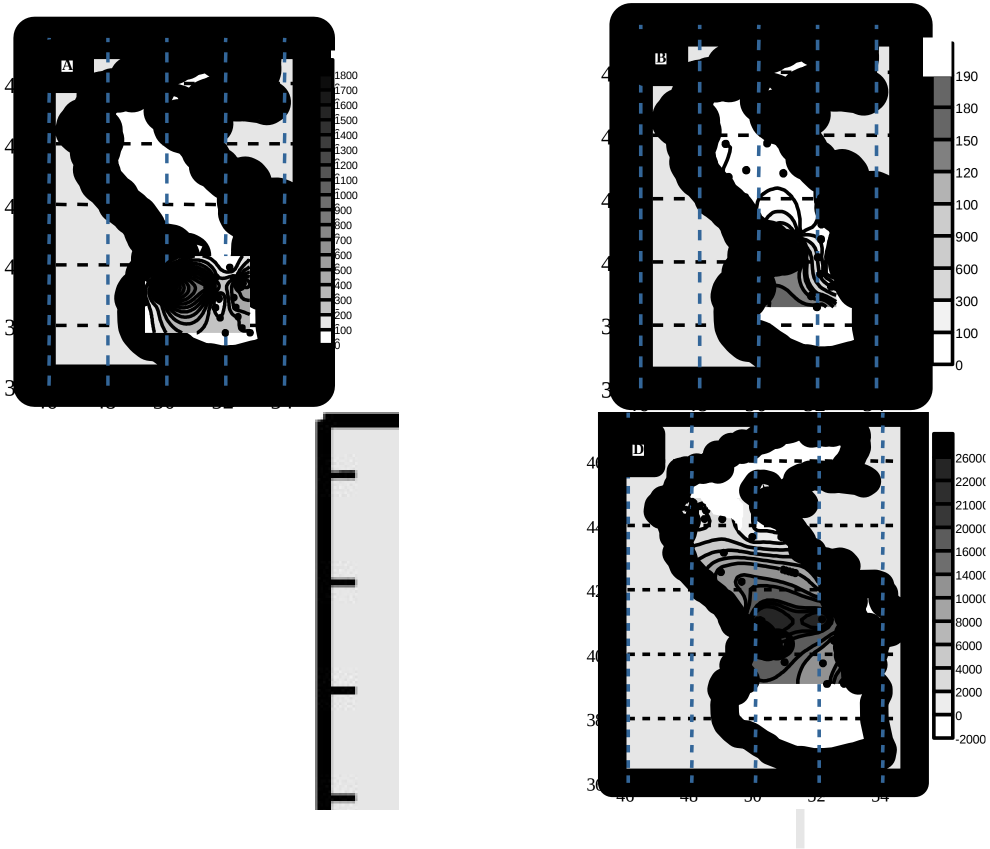

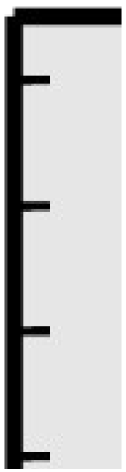

``Fig. 7 Seasonal spatial distribution of M.leidyi A-in January, B- in June, C-in July, D-in August, E-in October 2001 (Shiganova et al., 2004a).

Its abundance and distance of penetration is determined by wind direction and speed of wind currents (Shiganova et al., 2003). The lowest concentration is usually recorded in eastern part of the Middle Caspian in the area of upwelling, where temperature is lower (Kamakin et al., 2009).

Predominance of western and south-western winds contributes to the earlier penetration of *M. leidyi* to the North. Distance of wind driving currents with high salinity determines the distance of its penetration in the Northern Caspian (Fig. 8, 9) (Shiganova et al., 2003).

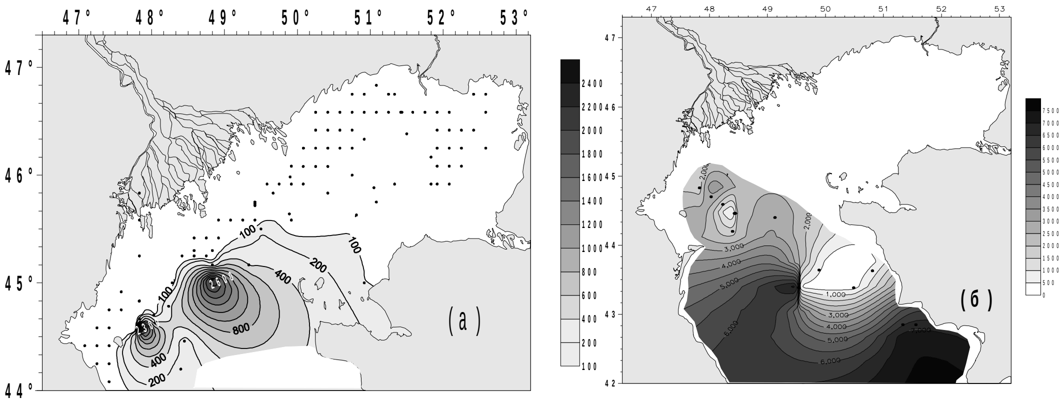

Fig.8. Distribution *M.leidyi* in August in the Northern Caspian*:* a- in 2002 b- in 2001 (after Shiganova et al.,,2003)**.**

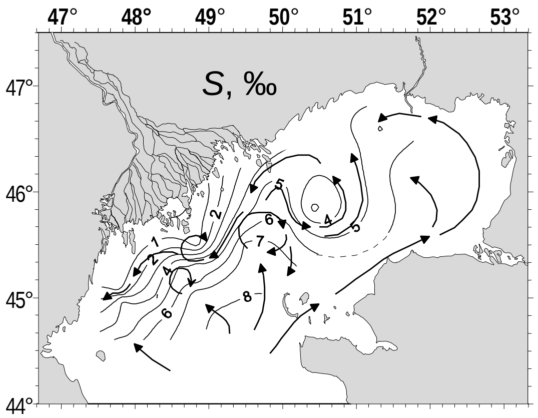

Fig.9. Pattern of salinity in the Northern Caspian in 2002 (after Shiganova et al., 2003).

The direction of prevailing winds and the temperature of the surface water layer in the area governed by the main Eurasian oscillations of large-scale atmospheric pressure, the North Atlantic Oscillation (NAO), and in the Caspian Sea more affected by atmospheric dipole-Atlantic East - West-Russian Oscillation (EAWR). Therefore, despite the definite seasonal distribution of *M.leidyi* in the Caspian Sea, there are interannual differences, determined by global climatic fluctuations (Kosarev, 2006).

M. leidyi may survive in the Northern Caspian in the water with salinity not less than 4‰ (Shiganova et al., 2001; 2003). *M.leidyi* usually occurred in the Northern Caspian in the western and central parts but almost did not occur in the eastern part until 2008. Only occasionally in some locations individuals were found but they were as a rule in bad conditions. Possible reasons could be the presence of high concentrations of particulate matter in the northeastern part and very low concentrations of zooplankton in the southeastern part of the Northern Caspian (Shiganova et al., 2003). But in summer 2008 *M.leidyi* was observed at 7 from 10 stations of the north-eastern Caspian (Report of Kazakhstan). Individuals were ranging in size from 5.1 to 10.0 mm. *M.leidyi* was abundant at the deeper stations where its values were highest (Table 2). At low salinity (1, 21-1,82‰), specimens were not found. In August 2009 ctenophore was recorded at 12 stations from 20 in the Northern Caspian. *M.leidyi* was not found at the stations with salinity less than 2‰. Maximal concentration was recorded at salinity 9‰ (Table 3; Report of Kazakhstan).

Table 3. Distribution of *M.leidyi* in the north-eastern Caspian in August 2008-2010 (Report of Kazakhstan).

Year	Depth, m	Temperature, ^{0}C	Salinity,‰	Abundance, ind./m^3	Biomass, g/m^3
Northern Caspian					
2008	3,0 – 3,9	26,7 – 29,2	7,9 – 9,1	3 - 22	0,01 – 2,6
	4,1 – 8,4	27,4 – 28,2	2,8 – 8,5	10 - 40	0,6 -6,7
2009	2,8 – 4,8	22,7 – 29,4	4,4 – 9,9	10 - 64	0,5 – 7,8
	2,8 – 4,2	26,6 -28,1	0,6 – 1,9	-	-
	5,5 – 8,9	25,3 – 28,0	8,3 – 9,9	9 - 38	0,5 – 6,9
2010	2,3 – 3,7	23,9	3,2 – 6,8	-	-
	2,9 – 5,1	23,4 -28,3	5,0 – 11,4	21 - 232	1,9 -7,4
	5,8 – 8,0	23,6 -28,1	9,4 -14,3	9 - 150	0,6 – 7,0
Middle Caspian					
2009	4,8 – 12,0	15,2 – 23,6	13,0 – 14,5	1 - 25	0,03 – 3,2
2010	23,0 – 26,5	6 - 8	13,8 – 14,1	7 - 10	0,6 – 1,2

The highest *M.leidyi* abundance was recorded in August 2010 at salinity more than 11, 1‰. Smaller size individuals occurred above the depth 3,7 m than above the depth 6 m. Concentration of ctenophores was approximately in two times higher in 2010 than in 2009 (Fig 10, table 3).

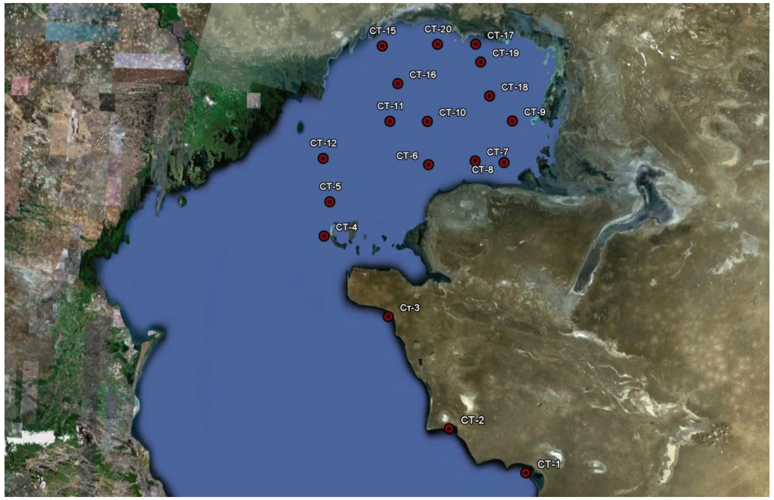

Fig. 10. Distribution of *M.leidyi* in the northeastern Caspian in August 2010 (Report of Kazakhstan).

In late autumn with decrease temperature *M.leidyi* eliminates first from the Northern Caspian than from the most of the Middle Caspian and small part of population, which consists of individuals of new generation stay in the Southern Caspian for overwintering (Shiganova et al., 2004b). In winter aggregations and individuals of *M.leidyi* occur in deeper areas, they were found at the depths up to 100 m in the Southern Caspian. Due to low temperature in the coastal waters the abundance of *M.leidyi* is low or they were not found in areas where temperature lower than 5, 3 ^{0}C. The highest abundance (409 ind.m^{-3}) was recorded in open waters of the Southern Caspian in February in warm 2004 (Kamakin et al, 2009). However in warm years *M.leidyi* can penetrate in the Middle and even in the Northern Caspian (2004) in winter (Kamakin et al., 2009; Shiganova, 2009). In cold and relatively cool winters (2001-2003; 2005; 2008) the Northern Caspian may be covered by ice and *M.leidyi* individuals never were found (Kamakin et al., 2009).

Seasonal dynamics and numerical values of *M.leidyi* are different in different regions of the Caspian, but it reaches peak of abundance and intensity of reproduction in August –September in all areas.

Summing up we may conclude there is a very dramatic trend in *M.leidyi* spatial and interannual distribution now. During last years it increased abundance in the Middle Caspian and particularly in the Northern, the highest increase was recorded in August-September during its peak of development (Fig.6). In addition *M.leidyi* spread in the northeastern Caspian (Fig.10) where it almost did not occur before 2008. In warmest 2010 its abundance was the highest there for the first time.

3.2. Impact of *M.leidyi* on the Caspian ecosystem.

Ctenophore *Mnemiopsis leidyi* reached a very high abundance in the years of the most intensive development, which was not observed in the Black Sea. Accordingly, the effect on the Caspian ecosystem was even faster and stronger. The functioning of the ecosystem changed in the same way as that of the Black Sea. Cascading effect occurred at the higher trophic levels, from a decreasing zooplankton stocks to collapsing planktivorous fish to vanishing predatory fish and seal. Similar effects occurred at lower trophic levels: from a decrease in zooplankton stock to an increase in phytoplankton, released from zooplankton grazing pressure. The majority of these effects were top-down, but few were also bottom-up (Shiganova et al, 2004b).

3.2.1. Change of physical parameters of environment. Because mucus released by *M.leidyi* the water transparency has decreased in the western part of the Northern Caspian Sea from 1.7-2.1 m to 0.6-1.2 m. (Shiganova et al., 2003). In the southern Caspian from 5-7 m to 1 - 4 m depending on season and distance from the shore (Roohi et al., 2008).

3.2.2. Change of hydrochemical parameters of environment. Special studies in the North Caspian in August 2002 showed that in the areas with greatest concentration of *M.leidyi*, decrease in oxygen, silica, pH were observed, but levels of inorganic phosphorus, ammonium, nitrate and nitrite significantly increased and C_{org} particularly increased (Shiganova et al., 2003).

3.2.3. Impact on mesozooplankton

Zooplankton stocks usually increase in summer due to the seasonal development of warm-water species of Cladocera, Copepoda and meroplankton, mainly consisting of larvae of Bivalvia and Cirripedia. Summer peak of zooplankton is usually observed in June in the Southern Caspian, and in July in the other areas of the Caspian Sea. This peak coincides with the beginning of intensive development of *M.leidyi* in the southern Caspian and the beginning of its dispersal to other areas of the Caspian Sea. Starting intensive development and spreading to the North *Mnemiopsis leidyi* reaches its peak of development in August in all regions and this time there is the most significant drop in zooplankton stocks. Zooplankton abundance and biomass started decreasing as early as in 2000, compared with pre- *Mnemiopsis* years (Shiganova et al., 2001; 2004b; Roohi et al., 2010).

Seasonally abundance, biomass and species diversity of zooplankton and meroplankton decrease from month to month during the summer and fall with increasing abundance of *M.leidyi* (Shiganova et al., 2004b).

Using the experimental data on the daily nutritional demands of *M. leidyi* only in terms of its costs on the metabolism without its costs for growth and reproduction seasonal variations of food demands of *M.leidyi* population were calculated. It was assessed that, despite the ongoing seasonal development of zooplankton, all of its stocks were lower than the calculated daily nutritional demands of *M.leidyi* in all areas of the Caspian Sea (Fig.11) (Shiganova, et al., 2004b).

Fig.11. S

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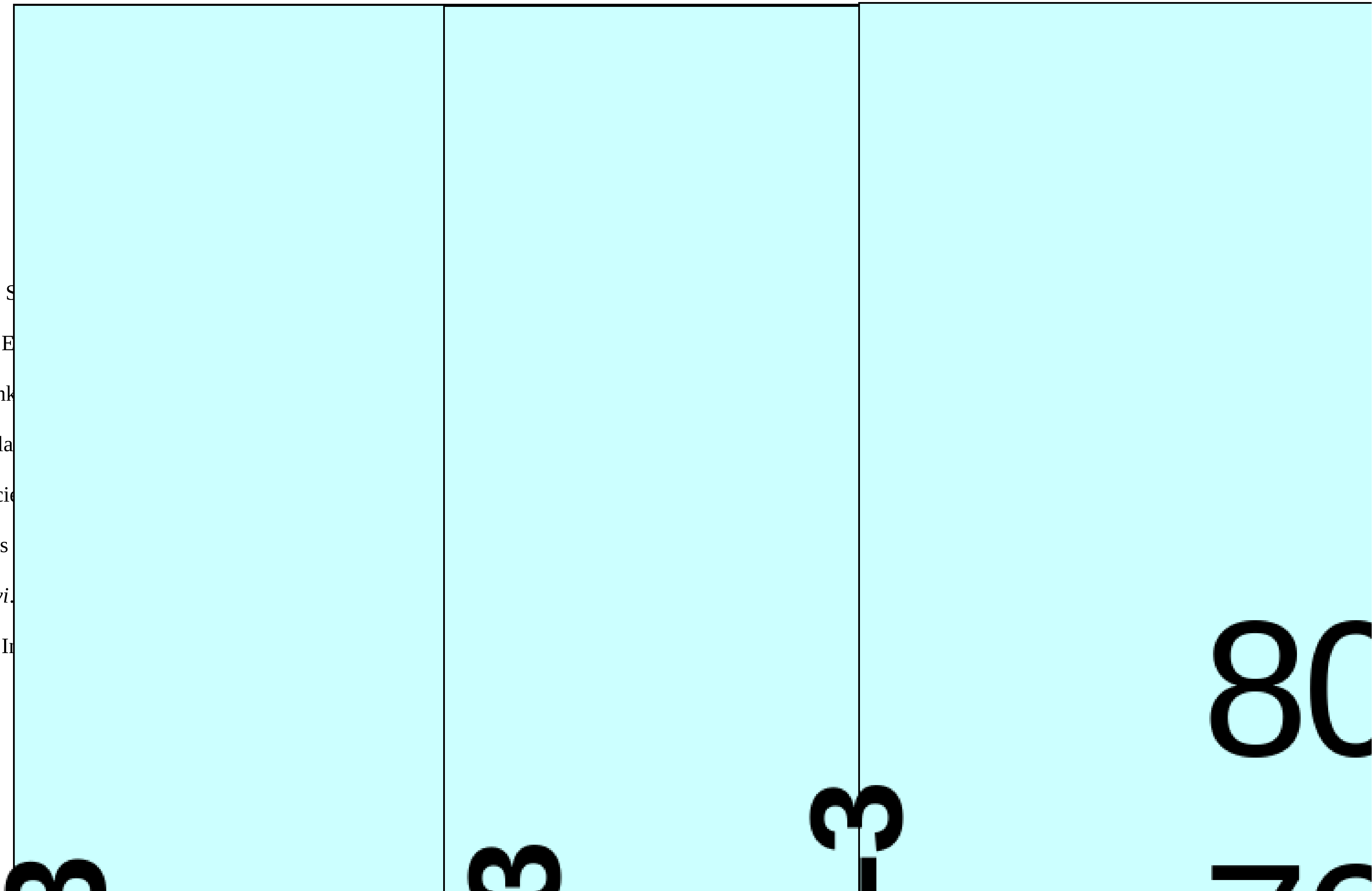

Thus, studies of zooplankton in the 11 years of *M.leidyi* development showed that both the quantitative characteristics and species composition changed significantly in the Caspian Sea. Abundance and biomass have decreased in many times, especially their significant decrease observed during summer and late autumn. The number of species dropped to 6-8 in warm seasons in the Southern (Fig.12) and to 2-4 in the Middle Caspian. Key species of edible zooplankton *Eurytemora grimmi, E.minor, Limnocalanus grimaldii, Calanipeda aquae-dulcis* etc., which were the main food items in planktivorous fish feeding almost disappeared. Now zooplankton including meroplankton comprises mainly of non-native species more resistant to aggressive invader pressure. Copepoda represent mainly *Acartia tonsa,* which contributes from 70 to 98% abundance and biomass of total zooplankton. Cladocera represents mainly *Pleopis polyphemoides* in most of cases in summer. Meroplankton besides larvae of Bivalvia (among them larvae of introduced *Abra abra*) represents nauplii and cyprises *Balanus improvisus* and larvae *H. diversicolor* (Tinenkova, Petrenko, 2004; Shiganova et al., 2004b; Roohi et al.,2010).

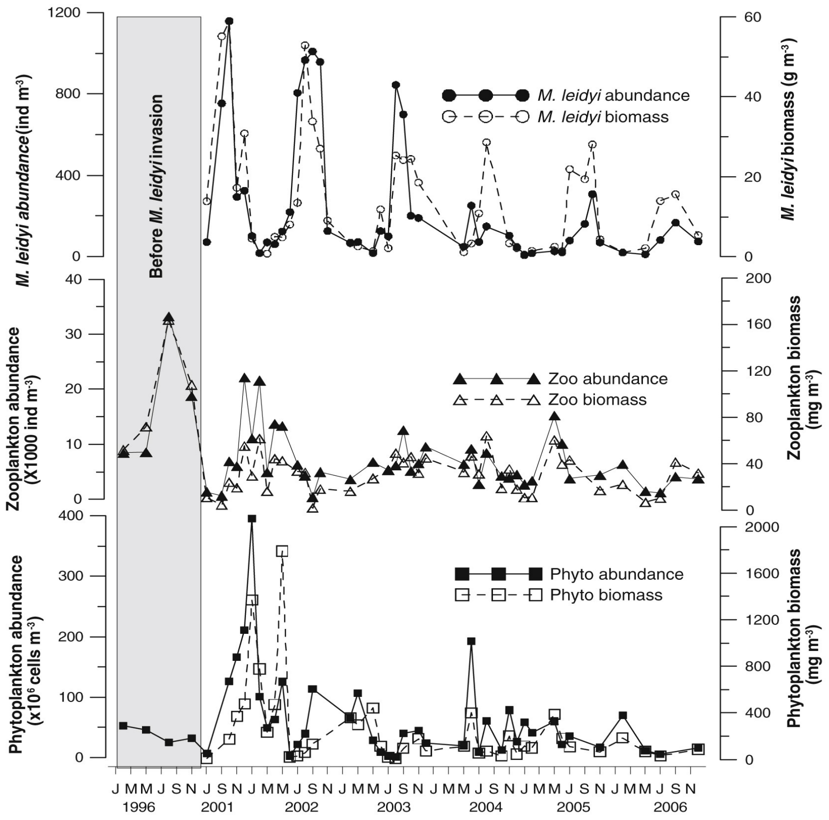

Fig.12 Interannual variability of *M.leidyi* (abundance and biomass),zooplankton and phytoplankton abundance in Southern (Iranian) Caspian Sea (After Roohi et al., 2010).

In the brackish waters with salinity lower than 4‰ abundanc does not occur and zooplankton abundance, biomass and species diversity did not change. In the north-eastern Caspian also zooplankton did not change yet in spite of penetration of *M.leidyi* there during last years (2008-2010) (report of Kazakhstan)

3.2.4. Impact on phytoplankton. Since 2001 abundance and biomass of phytoplankton have significantly increased reliesed from decreasing pressure of zooplankton. A significant seasonal increase in phytoplankton is usually observed from June to August (Shiganova et al., 2004b).

Features of phytoplankton development have become reducing the number of species of diatoms and dinoflagellates and increasing in the number of green and especially blue-green algae. There has been an overall increase in small-cell phytoplankton (Polyaninova et al, 2003; Roohi et al., 2010).

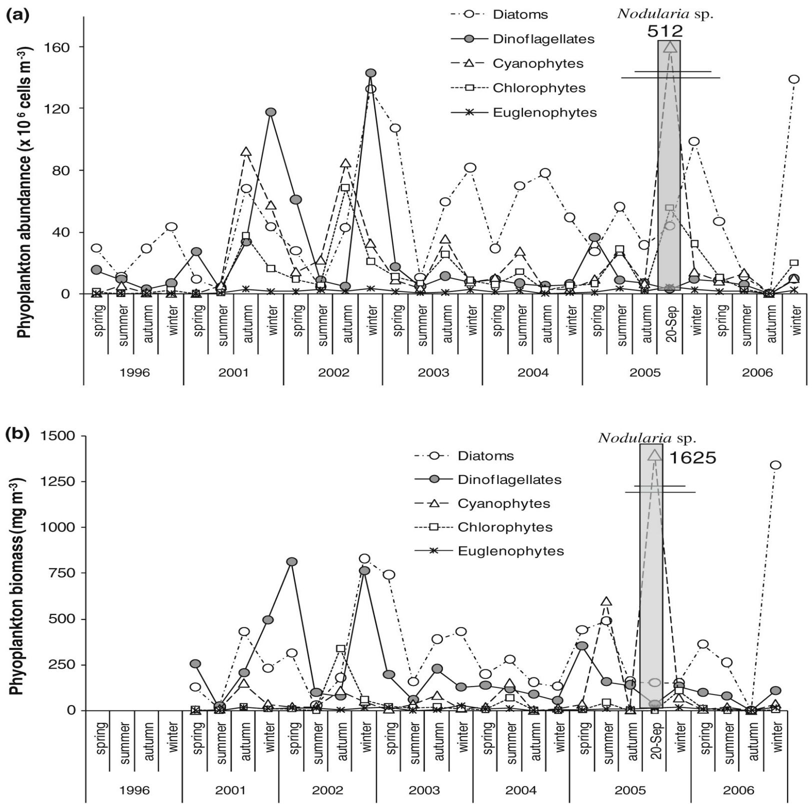

Fig.13. Change in abundance, biomass and species composition of phytoplankton in the Southern Caspian (after Roohi et al., 2010)

In September 2005 the intensive bloom of green-blue alga *Nodularia spumigena Mert.*was recorded for the first time in the Southern Caspian (Fig 14).

Bloom area covered 20,000 km^2 (Roohi et al., 2010).

Fig.14. «Bloom» of *Nodularia spumigena* in the Southern Caspian in August 2005 (after A. Roohi et al., 2010; Iranian report).

Another cyanophyte *Oscillatoria sp.* had also “bloom” at that time. Abundance of *Nodularia spumigena* was $18 \cdot 10^6$ cells m^{-3} above the depth 20 m. Average cyanophytes abundance and biomass were $582 \cdot 10^6$ cells m^{-3} (of which $512 \cdot 10^6$ cells m^{-3} was *N. spumigena*) and 1,655 mg. m^{-3} respectively above the depth 7 and 20 m. (Roohi at al., 2010).

Recent Black Sea invaders *Cerataulina pelagica* и *Pseudo-nitszchia seriata* widely distributed and their share in total phytoplankton biomass became significant in the Middle and Southern Caspian (Shiganova, 2009).

The increase in the biomass of phytoplankton has led to an increase in primary production. So in the measurement of chlorophyll "a "in the Northern Caspian Sea in August 2002, was found to increase its value in 2 times in comparison with the same season of 1999. (Shiganova et al., 2003). Data on the distribution of chlorophyll, obtained with the use of satellite scanner SeaWiFS also showed an increase in the values of chlorophyll in the Middle Caspian in 2 times in August-September 2001., and in the South in 3 times in comparison with 1999 (Kopelevich et al., 2002).

3.2.5. Impact on zoobenthos.

Since 2000 there has been a steady decline in the number of benthic organisms having pelagic larvae in the areas of the Caspian Sea where *M.leidyi* is abundant. In 2002, especially noticeable changes in the numerical indicators and the species were marked in the Southern Caspian Sea, where the total biomass and abundance were much lower compared to 2000: 3,3 g.m^{-2} and 1,5 10^3 ind.m^{-2}. There were almost no mollusks, which have pelagic larvae (Polyaninova, et al., 2003).

Abundance and biomass of the representatives of zoobenthos significantly decreased also in the western part of the Northern Caspian, where regularly penetrates *M.leidyi* and which is the most important area for fish feeding. The biomass varied from 0.03 to 238, 4 g.m^{-2} and on the average made up 31,0 gm^{-2} in 2003, which is 34% below 2002, and almost 3 times lower the long-term average annual for the 1978-2003. Abundance of benthos decreased from 13 to 10·10^{3} ind.m$^{-2.}$ The main benthic fauna, as before, were mollusks, which accounted for 75%. The average biomass of Bivalvia was much lower than a long-term average annual and amounted to 23, 4 g.m^{-2}. However in 2003 when *M.leidyi* appeared much later, their number was almost in 2 times higher, than in 2002.

In the shallow waters of the north-western and central Caspian crustaceans representatives of demersal plankton are available for *M.leidyi*. Their number decreased in 2003 compared with 2002 in two times from 5772 to 2309 ind.m^{-2} (Ardabiyeva et al., 2004)

In 2005, despite a slight decline in the population of *M.leidyi* after 2003 also marked by low values of the abundance of bivalve mollusks in the composition of the benthic fauna in the North –western Caspian (Ardabiyeva et al., 2006). In shallow areas, where *M.leidyi* abundance was highest, the biomass of the zoobenthos was the lowest. So in the Northern Caspian its biomass decreased in 3,5 times due to the reduction of biomass of bivalves and benthic crustaceans (Ardabiyeva, et al.,2006). Among bivalve mollusks have dominated non-native species *M. lineatus* and *A. ovata*.

In the Southern Caspian species composition and ratio of benthic species also greatly changed. During 2001-2006 annelids contributed most to the total macrobenthos abundance (250±109 ind.m^{-2}), followed bivalves (40±35 g.m^{-2}) and crustaceans (14±5 ind.m^{-2}). Before *M.leidyi* invasion crustaceans were the most abundant group in 1996 (1,000±418 ind.m^{-2}). After *M.leidyi* invasion crustaceans decreased by 98%. Macrobenthos community shifted from filter-feeding group of crustaceans to deposit-feeding annelids (*H.diversicolor* and oligochaetes) during 2001-2006 (Fig. 15) (Roohi et al., 2010).

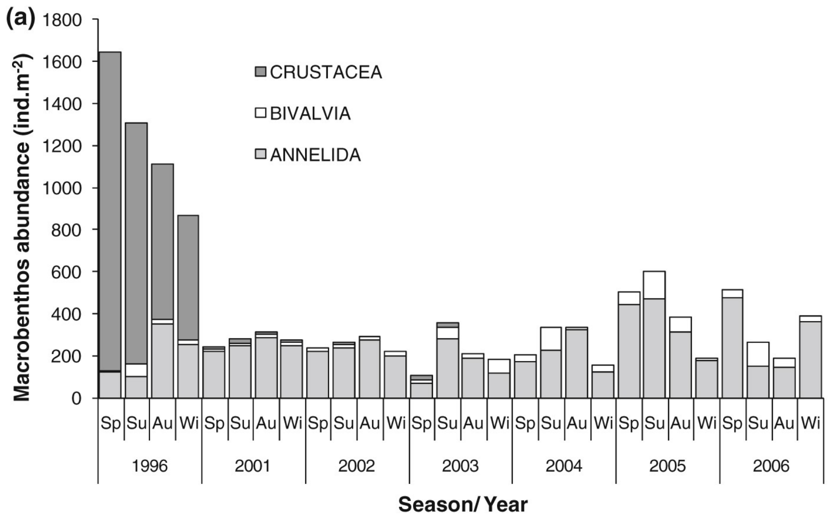

Fig. 15. Change of abundance and species composition of zoobenthos in the Southern Caspian (after Roohi et al., 2010).

3.2.6. Impact on fish stocks and fishery.

Planktivorous fish are the main food competitors of *M. leidyi*. In the Caspian Sea among them the most important three marine species kilka: common kilka *Clupeonella curtriventris* (Nordmann, 1840) (= *C. delicatula caspia)*, anchovy kilka *C. engrauliformes* (Borodin 1904) and big-eye kilka *C.grimmi* Kessler 1877, which comprised 70-80 % of total fish catch in the Caspian (Ivanov, 2000, Mamedov, 2006).

After invasion of *M.leidyi* the total catch of kilka of all Caspian countries dropped in all areas. The catch of kilka by Russia, Azerbaijan and Iran dramatically dropped from 182 700 t in 2000 to 58 800 t in 2001, although the total allowable catch remained at 300 000 t. Beetwen 2000 and

2004 the catch of Azerbaijan alone dropped from 18 500 to 5100 t. (Mamedov, 2006). The most likely primary cause of the stock collapse is the invasion and spread of the ctenophore Mneniopsis leidyi in the Caspian Sea. The dramatic recruitment failure of anchovy-kilka from 2001 to 2004 is primarily attributed to competition/predation by this ctenophore/ although other factors, including overfishing, likely contributed. (Daskalov, Mamedov, 2007).

Among them stocks of the anchovy kilka *Clupeonella engrauliformis* and big-eye *C. grimmi* have greatly decreased. Anchovy kilka is traditionally the most abundant fish species in the Caspian Sea . For a long time it was the main commercial fishery contributing some 75-80 % o0f the total catch of kilka. Anchovy kilka have daily vertical migration, following the plankton to the upper water levels in the day time and descending to the deeper levels at night. The main food is Copepods, mainly *Eurytemora* and *Acartia.* The main fishing area and feeding grounds is the Southern Caspian. There is a significant overlap with *Mnemiopsis leidyi* in timing, depth and preys and competition between the two could be crucial (Sedov, 2004).

Low biomass and slower somatic growth of the anchovy-kilka in 1999 – 2001 might be effect of drop zooplankton stock (Daskalov, Mamedov.2007) (Fig.16).

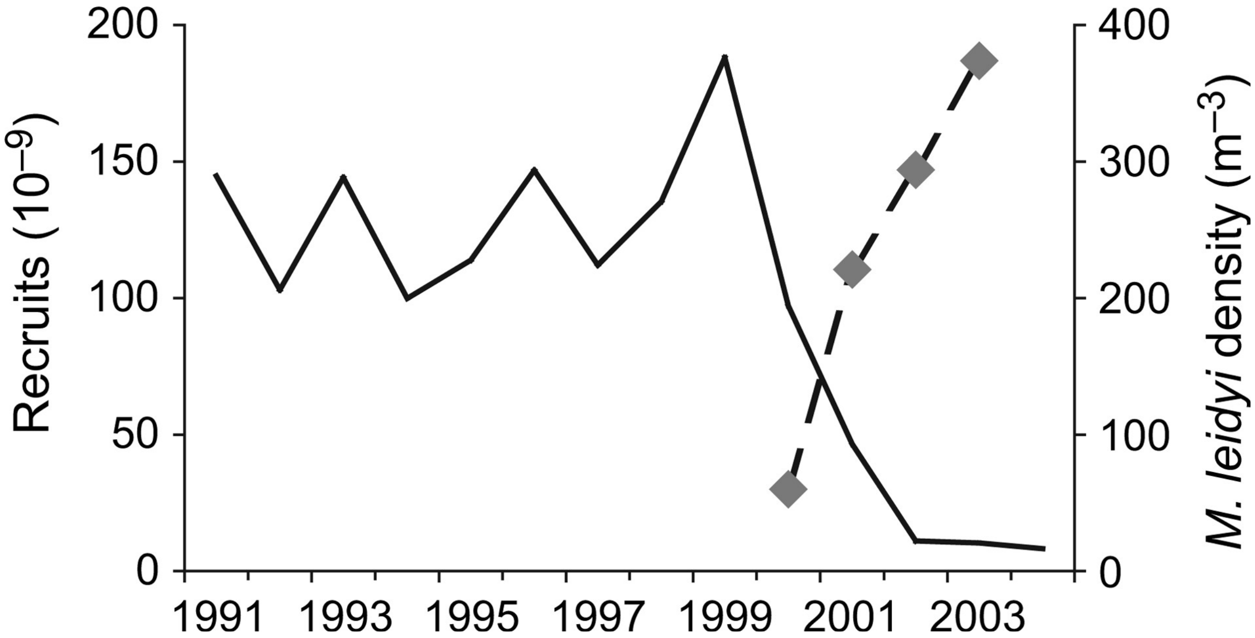

Fig.. 16. Kilka recruitment estimated by ICA (line) plotted against *M. leidyi* density (broken line and diamonds).

Only *Clupeonella cultriventris* has survived because of its wide ecological tolerances and capacity to migrate for feeding in brackish and fresh waters (Fig.17) (Zarbalieva et al., 2006). It has also spread widely into brackish and fresh waters in the Volga River basin (Osipov, 2006).

Fig. 17. Percentage of kilka species in total kilka catch (after Kostyukhin et al., 2006).

Total kilka catch by the end of 2001 comprised $54,8 \cdot 10^3$ ton, which in 2 times lower the level of 2000. Reduced kilka catch was observed in almost all Caspian countries, but the degree varies. So, Kazakhstan has completely stopped kilka fishing. Catch of Iran dropped on 73 %, Russian catch decreased on 62 %, Azeri catch decreased on 38%, but Turkmen catch was at the level of 2000 (Fig.18)(Sedov et al.,2004).

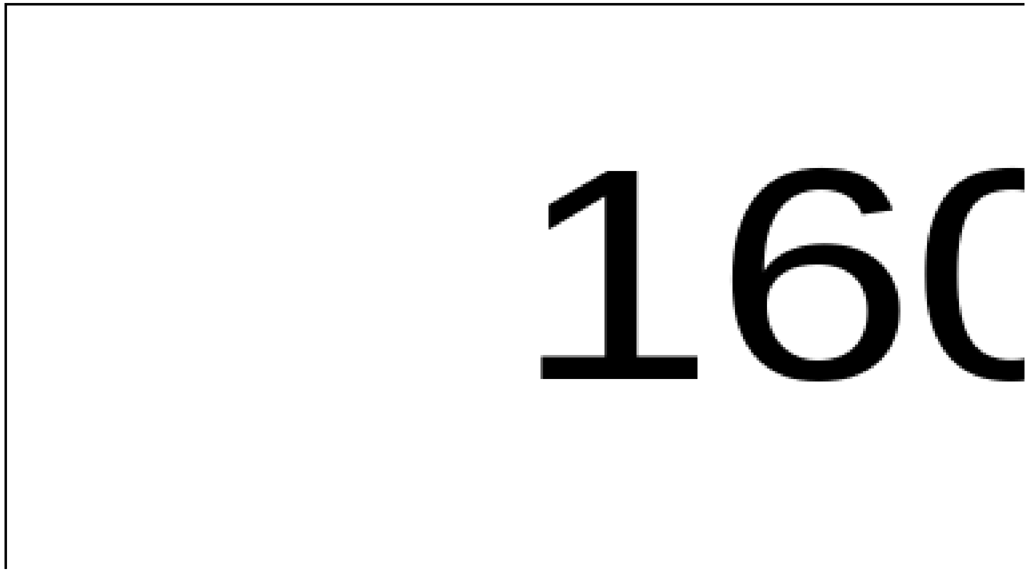

Fig.18 Total kilka catch per country in first years after *M.ledyi* invasion (after Sedov et al., 2004).

Catastrophic decline in stocks has led to unprofitable kilka catch with the light. From the 24 Russian ships only 13 remained for fishery in 2004. Accordingly, the decreased time spent on catching per vessels: there were 8807 ship-days for fishing in 2000, 8475 ship-days - in 2001, then only 4847 ship-days remained by 2004 (Fig. 19) (Kostyurin et al, 2006).

Fig. 19. Efficiency of Russian kilka fishery in 1999-2005 (after Kostyurin et al., 2006).

Additional factor, which affected kilka stock was mortality of anchovy and big-eye kilka stocks in the Middle and Southern Caspian (with exception of Iran) in spring 2001, which never recorded before in the Caspian Sea. Reseach of CaspNIRKH showed that the main reason was geodynamic instability of the Caspian Sea basin in spring 2001. This impulse of instability, probably served as one of the main reasons for the sharp cooling of sea water due to the effect of throttling of huge volumes of incoming gas from the earth interior, toxic contamination of water with hydrogen sulfide and methane (possibly in combination with arsenic and other heavy metals). As a result there was a massive loss of kilka and deterioration of the physiological condition of the surviving animals (Sedov et al., 2003).

During last years kilka catch did not increase and even decreased in all countries.

In 2009 Russian quota of kilka (65,04 thousand ton) was achieved only on 6,8%. Catch of kilka (anchovy, big-eye and common) was the lowest. Stock of the former main species anchovy kilka was in depression since 2002 and it was the same in 2009. Big-eye kilka stock was also in depression in 2009, it was lower long-term annual. Biomass was estimated at the level 5, 0 $\cdot 10^3$ tons, including commercial stock – 4, 40 $\cdot 10^3$ tons (in Russian waters – 2, 14 $\cdot 10^3$ tons). That was 16% below level in 2008. Only the common kilka stocks were characterized by stability and high level. Its commercial stocks were estimated in the volume of 400.0 $\cdot 10^3$ tons, including 271.0 $\cdot 10^3$ tons for Russian waters (Russian report).

Long-term analysis of Azeri commercial stocks of Caspian kilka shows that they were highest in 1999, and in 2001 dropped sharply, which affected the fishery. Kilka catch was 11 $\cdot 10^3$ tons in 2002 and only about , 2 $\cdot 10^3$ tons in 2007. They continue to decline from 1000,0 $\cdot 10^3$ tons in 2008 to 839,1 $\cdot 10^3$ tons in 2009. (Table 3). Kilka fishing in Azeri is now based also on the coastal form of common kilka , which comprised 78,3% of total kilka catch in 2009, anchovy kilka share was 20,9%, and share of big-eye kilka was only 0,8% (Azeri report).

Table 4. Change kilka catch ($\cdot 10^3$ tons, %) in Azeri after *M.leidyi* invasion (Azeri report)

Species	2002	2003	2004	2005	2006	2007	2008	2009
Anchovy Kilka	9143,4 (83,5%)	4882,1 (80,4%)	6334,26 (71,2%)	7896,0 (75,2%)	1965,4 (63,4%)	861,7 (23,5%)	341,0 (34,1%)	175,3 (20,9%)
Big eye Kilka	208,0 (1,9%)	30,36 (0,5%)	17,79 (0,2%)	294,0 (2,8%)	12,4 (0,4%)	33,0 (0,9%)	6,0 (0,6%)	6,9 (0,8%)
Common Klka	1598,7 (14,6%)	1159,8 (19,1%)	2544,38 (28,6%)	2310,0 (22,0%)	1122,2 (36,2%)	2772,2 (75,6%)	653,0 (65,3%)	656,9 (78,3%)
Total:	**10950,1**	**6072,26**	**8896,43**	**10500,0**	**3100,0**	**3667,0**	**1000,0**	**839,1**

The kilka stocks decreased in many times in Iranian part of the Sea and damaged many fishing activities and related jobs in the region especially in Iran (Fig. 20,21). Kilka fishing activities in south of the Caspian Sea that is carry out in ten months of year in Iran . Base on Kilka fishing method, the fish is attracted by light and then it is caught by funnel shape nets.

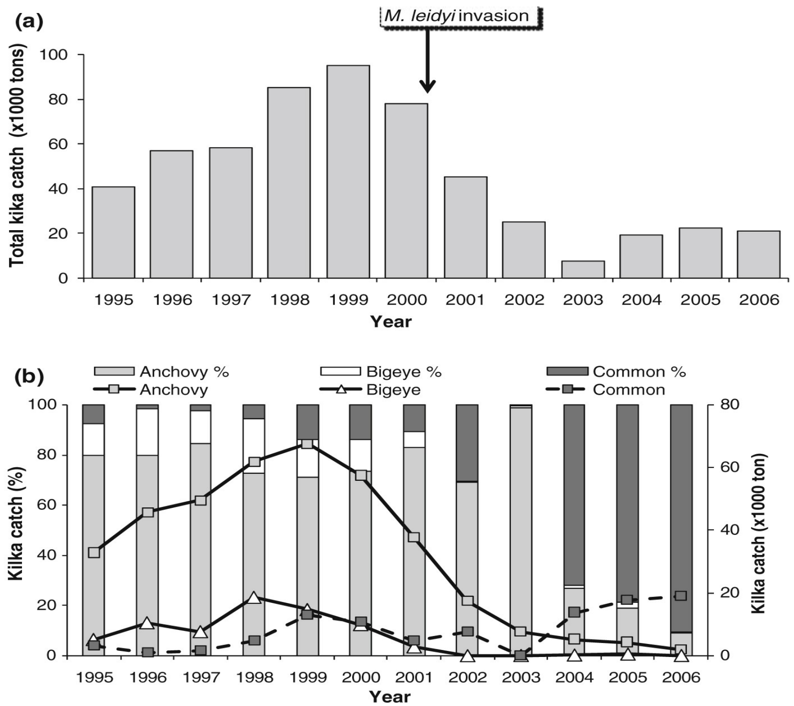

Fig. 20. (a)- total kilka catch and (b) share of kilka species in total kilka catch (after Roohi et al.,2010).

The harvested fish from the southern Caspian shows two fluctuations and three periods. First slope from 1989 up to 2000 with increasingly trend, second from 2001 up to 2004 with big slope and decline in catch and third period after 2005 with a stable trend of catch. These fluctuations mostly were happened because of changes in kilka catch. Since 1989 the number of kilka vessels raised from 4 up to 198 in 2002 , the amount of kilka catch increased from 7902 tons in 1989 up to 95000 tons in 1999 more than 12 times. After invasion of *Mnemiopsis leidyi* into Caspian Sea (Esmaili et al, 2000) and starting competition between comb jelly and kilka for food, the kilka stocks dropped up to 2003. Kilka fishing vessels were decreased from 200 to 80 active vessels due to collapsing of kilka stocks after *M. leidyi* invasion. In this way Iran Fishery Organization paid a huge amount of money to frank the fishermen licenses and bought their vessels and licenses. Actually Iran Fishery Organization beside of declining in fishing efforts has tried to create an opportunity to fishermen to start another business (Iranian report).

After 2004, the fish stocks were recorded as a stable at rather low value in Iranian area. These fluctuations in the fish stocks influenced the amount of catch in the Caspian Sea. It would aim to conserve and utilize the living aquatic resources, including the management of fish stocks such as kilka, herrings and mullets, as well as the famous sturgeons. Although the amount of catch in 2009 in south of the Caspian Sea (44279 tons) in comparison with the total product of fish in Iran (599754 tons) has been equal 7.4% and located in low level but the fishing activities in the sea is very vital for local people and their livelihood. Figure 20 shows the total catch of different fish in south of the Caspian Sea in during 1989-2010 (Iranian report).

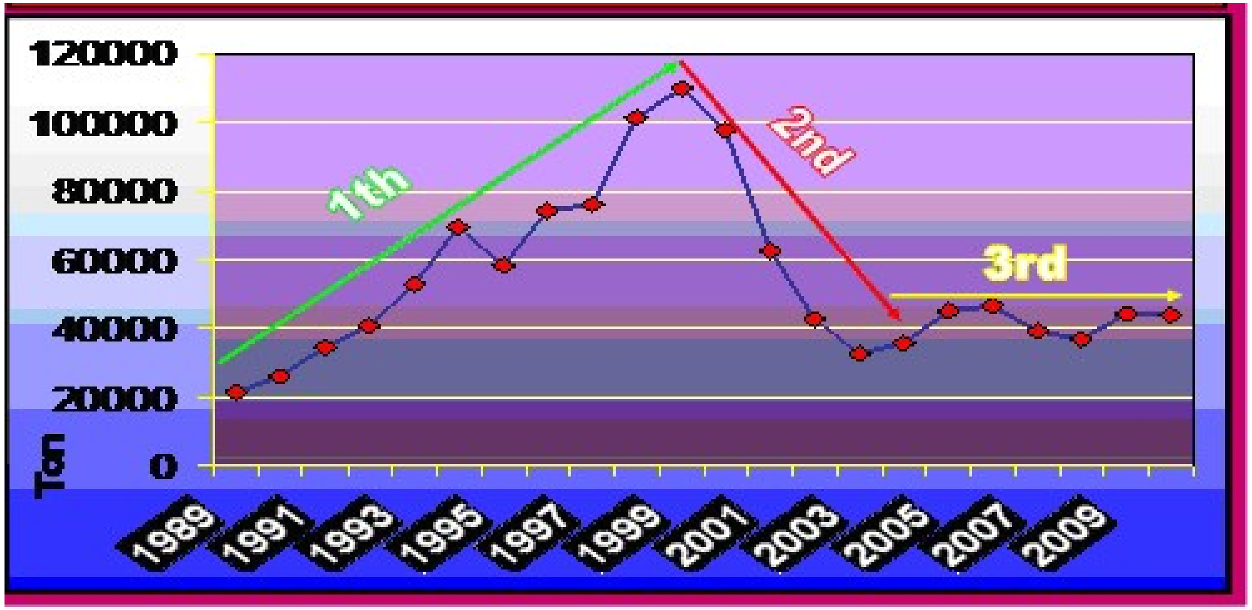

Fig.21. Iranian total catch of all commercial fish (Iranian report).

In the Northern Caspian main fish stocks are based on ordinary fish, which are also planktivorous. After *M.leidyi* invasion in the food of roach marked decline in the food items of the larvae of mollusks and crustaceans, but the overall indices of stomach fullness were not low due to wide food spectrum and usage other food items (Sokolsky et al., 2006). Stocks of Caspian marine planktivorous shads *Alosa brashnikovi* and *Alosa caspia caspia* decreased due to decreased food supply . Declines of their biological parameters were recorded (Sedov et al., 2004).

Azeri fishing for shad is in the south-western part of the Caspian Sea based mainly on local forms brazhnikovskih herrings *Alosa brashnikovi sarensis.* Mullet fishing in Azerbaijan in 2002-2007 tends to increase, reaching in 2007 more than 60.0 tons (Azeri report).

Thus, *M.leidyi* greatest influence has been recorded on marine planktivorous fishes, first of all on stocks of anchovy kilka and big-eye kilka. Before *M.leidyi* invasion anchovy and big-eye kilka comprised from 79 to 90% of the total kilka catches of all Caspian countries. Common kilka, due to environmental plasticity and euryhalinity did not suffer. However, its indexes of filling and the size-weight characteristics in the sea have decreased.

3.2.7. Impact on sturgeons. Representatives of the sturgeon are a unique treasure of the Caspian Sea. At the present time, according to Russian surveys in 2005 in trawl and net catches Russian sturgeon *Acipenser gueldenstaedti* Brandt has traditionally held a leading position 86, 5 and 95.0% respectively (data of summer surveys). The stellate sturgeon *Acipenser stellatus* is on the second place (11,2% by the results of trawl catches and 1.0% on the net catches), on the third place is beluga *Huso huso* (1,92% and 4% , respectively). The share of the barbel sturgeon *Asipenser nudiventris* is minimal - 0, 38% (Romanov et al., 2006). One of the factors, which determine the state of sturgeon stocks, is their food. As a result of *M.leidyi* invasion changed the composition of food sturgeon, diets, and reduced indices of stomachs fullness.

According to Prikhodko (1975), the annual consumption of kilka by predators such as sturgeon and Caspian Seals was about 400, 000 t in the early 1970s when sturgeon and seal stocks were large. As a result after the introduction *M.leidyi* the food spectrum of sturgeon changed as in benthic feeders (Russian sturgeon, starred sturgeon), and predators (beluga). In the nutrition of benthic feeders valuable species of molluscs decreased considerably of which the main prey species, not previously used in food has become alien species *M. lineatus*, and introduced *Abra abra*, and *H. diversicolor*. Kilka practically has disappeared from the rations of all species of sturgeon, including the predator beluga. Only common kilka in very small quantities was found in their diets. Indexes of stomach fullness in the most of areas of the Caspian Sea have become very low.

The impacts on the sturgeon stocks are multifaceted, so it is difficult to determine the impact of *M.leidyi*, but comparing with years before *M.leidyi* arrival a decrease in the number of sturgeons has been recorded in all species as well as in their morphological parameters (Romanov et al., 2006). So beluga is found in research catches in single individuals. The catch per effort in the Middle Caspian Sea were 0.06 ind. traul in 2005., in the Southern -0,019 ind.traul, which is 2.1 times less than in 2004 parameters (Romanov et al., 2006).

3.2.8. Impact on Caspian seal *Phoca caspia*

The Caspian seal, *Phoca caspica*, is the only marine mammal in the Caspian and is an endemic species. The seal was a relatively small-bodied and numerous species, with a total estimated population in 1900 of about 1.5 million animals giving birth to 300–400 thousand pups annually (Härkönen et al., in preparation). The population has declined by more than 90% over the past century to a maximum of about 100 thousand animals giving birth to about 21,000 pups in 2005 (Härkönen et al. 2008; in preparation).The impact of the outbreak of *M.leidyi* on the Caspian seal has been particularly significant in the first years (2000-2002). This happened because of the sharp fall in stocks of anchovy and big-eyed kilka, the first of which was about 60% of food items of seal. As a result, average weight of seals decreased by 10% in 2001 compared with 2000, the percentage of breeding females is significantly decreased. Total barrenness was 79.8% of all females; the percentage of pregnant females was only 10.1% in 2001. After 2002 first the reduction of the population of *M.leidyi* occurred, and second the replacement kilka other fish species in seal food compositions in the brackish areas of the Northern Caspian where *M.leidyi* can not occur due to low salinity. This has led to the improvement of the state of its population and reproductive capabilities of females (Khuraskin, et al., 2006). . In addition, profound changes to the ecosystem resulting from anthropogenic introduction of alien species and over-harvesting of sturgeon and bony fish may mean that the potential for population recovery of the

Caspian seal may be limited. All of these factors contributing to the species decline. In October 2008, the IUCN status of the Caspian seal was changed from ‘vulnerable’ to ‘endangered’.

Thus invasion of the Caspian Sea by the comb-jelly *Mnemiopsis leidyi* has become a major environmental issue, threatening the fragile ecosystem of this globally unique water-body. *M.leidyi* rapidly expanded to reach critical biomass levels in important commercial areas of the Sea and jeopardizes ecosystem and the fisheries industries through an impending catastrophic impact on the food web in general and on pelagic fish stocks and seals.

In conclusion, the Caspian Sea example provides yet another illustration of the fact that a lower gelatinous carnivore invader, well adapted to rapid expansion, can suppress whole ecosystems and their functioning (Shiganova et al, 2004 a, b)

4. Recommendation on invasive species management and possibility of biological control of invader *Mnemiopsis leidyi*.

Summarizing this review we may conclude that invasive alien species are recognised as one of the leading treats to biodiversity in the Caspian Sea and also impose enormous economic damage on the Caspian fisheries. However we may conclude that some of the species became food items for fish when native species almost disaapeared after *M.leidyi* invasion.Therefore to ensure that time and money are used most effectively, it must be identified the defenetly invasive species (target species, pests) that truly harm biodiversity or have the potential to do so in favorable conditions or to increase abundance, to create bloom, dispersal further in new areas, to suppresе native species, to graze them. At present among all invasive species ctenophore *Mnemiopsis leidyi* is the most aggressive invader that affected all levels of the Caspian ecosystem and considerably contributed in decrease biodiversity and decline of fish stocks. This assessment of invasive species and their impacts on the Caspian ecosystem will help to define the starting point and basic opportunities for prevention and management of invasive species.

The previous report “Review of National Legislation on Introduction of Alien Species” focused on law and legislation, relating to the invasive species problem, which is important for actions to create of a single, unified law for the control of all kind of invasive species introductions (based on the Tehran Convention, Convention on Biological Diversity (CBD), its Cartagena Protocol, the UN Convention on the Law of the Sea, instruments under the International Maritime Organization, the Convention on Migratory Species and one of its subordinate Agreements, and the WTO and two of its subordinate instruments). Previous report also identified three non-binding instruments of particular relevance – the FAO Code of Conduct on Responsible Fisheries, the FAO Code of Conduct for the Import and Release of Exotic Biological Control Agents, and the CBD’s Guiding Principles on Invasive Species and two international bodies of importance on that issue – the UN Food and Agriculture Organisation and the World Organisation for Animal Health (formerly the “Office International des Épizooties”). Both last organizations are involved in developing standards for international control of pests and diseases, which may include material directly relevant to the control of at least some invasive species. Other bodies including the Global Invasive Species Programme and the IUCN Invasive Species Specialist Group may also be sources of information and technical assistance. For each of these instruments and bodies, previous report summarised their primary requirements and recommendations. In later sections, it considered how these requirements and recommendations apply to the Caspian countries, and particularly to the protection of the Caspian Sea from invasive species introduction.

In our report we stress four main options for dealing with non-native species:1. prevention, 2. early detection, 3. eradication, and 4. Control

In addition we considered as important the theoretical strategies for the control of invasions of marine and brackish-water organisms developed by the United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) in 1995. These measures should include mechanical, chemical, physiological and genetic controls, as well as ecological control by habitat modification and biological control.

4. 1. Prevention.

Three major exclusion measures to stop introductions are recognized in accordance to GISP: interception, treatment, prohibition. The first involves the succesful implementation of regulations at the order. A risk assessment should be carried out for every proposed intentional introduction. Species whose entry is either Permitted or Prohibited need to be included in a pied list to allow dissemination of the results of such assessments. Next, commodities suspected of being contaminated with non-native species need to be treated, and treatments should be specified in each case. Finally there is the possibility of prohibiting imports based on international regulations. Education is a key component of all prevention efforts.

The final section discusses the risk assessment process as a tool to support exclusion of species based on their perceived risk and to assess the potential impact of species already established. The objective of such an assessment is to predict whether or not a species is likely to become established and be invasive and to generate ranking of risk. Entire pathways may also be analysed for risk, and this may be a more efficient procedure where many possible species and vectors are involved (Wittenberg and Cock, 2001).

Our assessment has showed that after constaction of the Volga-Don Canal the main vector of alien species appearance is shipping foulings and ballast water discharge. Therefore the discharge of ballast waters into the sea must be managed according to the provisions of the Ballast Water Management Convention to prevent, reduce and ultimately eliminate the risks to the environment, human health, property and resources caused by the transfer of aquatic organisms and pathogens by ships. And it is crucial now for all Caspian countries to join “The International Convention on Ballast Water Management”

For the Caspian Sea this measure is the most urgent and important type of unintentional introductions is “ballast water,” which is reportedly the source of *Mnemiopsis leidyi* invasion and the current invasions of new the Black Sea zooplankton and phytoplankton species. Although none of the Caspian countries have ratified this agreement, it may still provide some useful guidelines for implementation of Article 12 of the Tehran Convention. Ballast water controls may be important in order to prevent further spread of *Mnemiopsis leidyi* and/or the introduction of other species to the Caspian or to different ecosystems within the Caspian.

As an enclosed sea, the Caspian has different kinds of ballast water problems from wider oceans. In particular, it may be necessary to reconsider the idea that ballast water discharges in “open sea” can be uncontrolled. In law governing wider oceans, there may be a distinction between the waters controlled by a particular country, on one hand, and “open sea” on the other. In those cases the “open sea” is so wide and deep that other ecosystemic functions are sometimes expected to address, eliminate or “re-sort” any new species that are discharged. It may be necessary, however, to consider the need to adjust the various international guidelines in the Caspian Sea, because the waters that are outside of one country’s jurisdiction are inside the jurisdiction of one of the other countries. Hence, if one country’s law says that it is acceptable to discharge ballast water beyond the limits of that country’s waters,[1] it is essentially transferring the discharge to one of the other littoral States. At present, some countries’ law allows ballast water discharges in “open sea” (waters beyond national jurisdiction) (Young, 2007).

Therefore it should be developed special actions adapted for the Caspian region to prevent introduction new alien species with ballast waters. It should be done in cooperation with GloBallast after joining to IMO Ballast Water Convention.

1

4.1.1 The 2005 IMO Ballast Water Convention

IMO's *International Convention for the Control and Management of Ships' Ballast Water and Sediments* ("Ballast Water Convention" or BWC)[2] directly addresses the prevention, minimisation and ultimate elimination of

> *the risks to the environment, human health, property and resources arising from the transfer of Harmful Aquatic Organisms and Pathogens through the control and management of ships' ballast water and sediments.*

Like the Cartagena Protocol, the BWC is very limited in scope, focusing only on one very particular shipping activity. Like the Cartagena Protocol, BWC Parties may adopt stricter measures if they wish (BWC, Article 2.3), and have a responsibility to address all alien and invasive species in marine areas, which responsibility is not limited by the BWC. (Articles 2.6 and 2.8.) In particular, BWC Parties should take legal measures requiring ships under their registry to comply with ballast water requirements, in other countries' marine areas.

The BWC's primary operative provisions (Articles 4 through 11) require that each country must implement many detailed operational provisions, including the following:

- Each country must designate "ballast water discharge areas" (areas which are less sensitive ecologically, and which can be monitored and restored, in the event that invasive organisms are found there) and maintain "adequate sediment reception facilities (the use of which does not cause undue delay) at ports and terminals where ballast water tanks may be emptied, cleaned or repaired."
- Each country must require that all ships utilise certain specified technologies for ballast water management and for eliminating live biological material prior to discharge of ballast water ("mechanical, physical, chemical, and biological processes, either singularly or in combination, remove, render harmless, or avoid the uptake or discharge of harmful aquatic organisms and pathogens within Ballast Water and Sediments,") and to develop and adhere to a "ballast water management plan."

[2] Adopted February 2004 (not in force.) The full text of the draft Ballast Water Convention is available on line at http://globallast.imo.org/index.asp?page=mepc.htm .

- Each country must keep records and require ships to keep records, must report to IMO), and must share records as well as scientific or other relevant information.
- Each Party must require all ships (including ships from countries not a Party to the BWC) to comply with discharge and technical requirements. To ensure compliance, each Party must also accept, legislate and implement governmental authority for monitoring, boarding, inspection and sanctions.

The Annexes to this convention set standards, and the BWC specifically notes that these standards should be regularly revised (BWC, Article 2.5.) Most important, for purposes of the current Report, the BWC requires its Parties to

> *ensure that Ballast Water Management practices used to comply with this Convention do not cause greater harm than they prevent to their environment, human health, property or resources, or those of other States (BWC, Article 2.7.).*

4. 2. Early detection.

National and international surveys must be organized and perfirmed for early detection of non-native species appearance in framework of national and international programs.

First of all the main attention must be paid to major shipping ports, which are often the first places that invasive marine species are introduced and become established. Port Biological Baseline Surveys (PBBS) are used to develop a baseline list of species – both native and non-native – that are present in a shipping port. Such lists can be used to communicate risks to other shipping ports or nations, as appropriate, and provide an essential reference point for ongoing monitoring and management of non-native species. As an activity targeted at marine pests, PBBS can also help raise awareness of marine pest issues within the region. Most importantly, they allow any existing introductions to be notified, tracked, and managed.

The compilation of comprehensive species inventories for individual ports plays a significant role in ballast water management. Risk assessment methodologies rely on the availability of data on the species present within ports. For a port to effectively manage the ballast water associated with its shipping movements, data must be available and complete from the local port as well as from the source ports for the ballast water being received. The quality of the risk assessments will depend on how complete the species inventories are for the ports with which it trades. It is important, therefore, that the methods and approaches used to compile a baseline list of species within a port are standardised among shipping nations.

PBBS can be logistically complex. They require good systems for sample collection, specimen handling, identification and analysis. Proper and adequate taxonomic expertise is required for identification of samples to species-level. As ports are hazardous environments, field work needs to be designed with safety in mind. Reporting mechanisms need to be well developed, so that if scientific teams detect a new introduction, management agencies are alerted in a timely manner (GloBallast Partnership (GBP)).

4. 3. Eradication

Eradiation – elimination from a site of all individuals of a species - is a management tool that allows us to prevent impacts caused by the undesired introduction of a non-native species. A more precisely, eradiation is the compplete and permanent removal of all wild populations of an no-native plant and animal species from the specific area by means of a time-limited campaign. Eradiaton should also be distinguished from the control of a species to zero density, which aims at the complete removal of the target species, but through a continued removal effort. Eradiation might be concucted using very different techniques depends on biology of species, enviroment where species live etc. Biological control agent or pathogens have been used in many removal programs but such methods should be viewed with caution and emplyed only after a carefull assessment of associated risk.

Unfortunately there is no methods to eradiate *M.leidyi*, but simultaniously with it another gelatinous species *Aurelia aurita* was introduced from the Black Sea. There were only few records of ephyra and medusa stages of *Aurelia aurita* in the Caspian, but it could be useful to distribute picture of this species among govermental, scientific and public organizations to register finding of Aurelia aurita individuals and in this areas to organize surveys for detection and removal of polype stage of Aurelia to stop its living cycle of development. Aurelia aurita findings were recorded in the Southern Caspian where salinity is highest therefore these observations should be orginized in these areas.

4. 4. Control.

4.4. 1. International Controls (after Young, 2007)

Controls on international movement of goods are relatively easy to apply in the case of large commercial shipments, for two reasons. First, the persons purchasing, selling and transporting material in commercial quantities are professionally knowledgeable of the rules relating to those materials. Second, enforcement is easier where the size of shipments makes them difficult to hide. As noted above, however, it is important to apply similar controls to individuals and to very small commercial shipments. It is also important to ensure that they are consistent with other systems which control other kinds of goods.

All five Caspian countries impose controls on some biological material passing international borders, however there is quite a bit of variation among them. In Turkmenistan, for example the primary restriction on biological material (“objects of flora and fauna and their derived products”) entering the country is the requirement that they must be declared at customs control. This provision provides the basis that enables veterinary and phytosanitary officials to check certificates of entering species, and impose quarantine measures where no certificate has been obtained. At present, these controls do not directly relate to invasiveness criteria, however it would be easy to apply them, if other sectors developed appropriate certificates, lists of controlled species or other invasiveness-oriented information. Russian law specifically calls on customs authorities to exercise a coordinating function, including supporting domestic legal measures for protection of animals, plant and the environment. In Iran, border controls on biological material are apparently limited to those mandated under CITES (which, as discussed in 3.3.3, does not address invasives issues.) In Kazakhstan, the law provides an express *right* of all citizens to transport goods across borders, which suggests that any control on potentially invasive species will have to be stated specifically. At present, the only relevant clauses control the movement of red-listed species and their parts.

While four of the five countries are Parties to CITES and have adopted the legislation required under that Convention, most have not extended their laws on the importation of wildlife beyond those described in 3.3.3. The exceptions to this are provisions, in Azerbaijan which require input from environmental authorities (in addition to the general provisions required under CITES for an import permit) before allowing import of the species. These provisions also can provide a basis for including invasiveness factors in the import decision, however, at present it does not appear that these factors are specifically addressed in this process. As noted in 3.3.3, even if they are very clearly revised to include invasiveness issues, CITES legislation will not apply to most invasives and pathways.

In reviewing national customs controls on invasive species, however, it is also important to keep practical matters in mind. Customs officials are not normally able to make scientific judgements about the risk that a seed or species could be invasive. Consequently, laws calling for customs to control the introduction of new species must be clear and objective, with specific descriptions of the materials of concern, and the conditions, permits or other measures to be verified at customs. For example, a law in the Russian Federation includes a general provision for customs to control the importation of "potentially harmful biological objects." This term has been suggested as possibly applying to invasive species, however, it is more commonly applied to specimens that are easily recognised in customs, including

- immediately and obviously dangerous animal specimens (poisonous snakes, large and ferocious creatures that are not properly contained, etc.),
- specimens that carry or may carry disease (*i.e.,* biological materials that have no phytosanitary or veterinary certificates) or
- sources of dangerous and/or non-pharmaceutical substances controlled under other important laws (seeds of opium poppies.)

4.4.2. Control of Potentially Invasive Species after Introduction (after Young, 2007)

There is also a need to consider post-introduction controls on species. Unlike introductions, these provisions are narrower in focus – they do not apply to all alien species, but only those that are "potentially invasive" – a term that includes species whose possible invasiveness is unknown, as well as those which have been identified as risky.) To protect against possible future invasion, countries must maintain some level of control over non-native species including –

- Risky species that are introduced with permission, subject to control;
- Pre-existing species that were *in-situ* at the time the control system was adopted;
- Species discovered in areas in which they do not belong, where the agency decides not to immediately eradicate or remove them, but instead to wait and see if they are invasive.

These controls should focus on rights and duties – the rights and duties imposed by government in issuing authorisation, the rights of landowners, and the special duties that are applicable to protected areas and species.

4.4.3. Biological control of target species.

Biological control is the deliberate use of a living species (biocontrol agent) against a target species (the pest). As showed our report the most aggressive invader and target species in the Caspian Sea is a ctenophore *M.leidyi* now. Invasion of the Caspian Sea by this comb-jelly has become a major environmental issue, threatening the fragile ecosystem of this globally unique water-body. *M.leidyi* rapidly expanded to reach critical biomass levels in important commercial areas of the Sea and jeopardizes the fisheries industries through an impending catastrophic impact on the food web in general and on pelagic fish stocks in particular, sturgeons and seals.

Among the factors that permitted the outbreak of *M. leidyi* was the absence of its predators.

Thus taking into account the importance of the problem and scale of anthropogenic invention into the Caspian ecosystem the possible courses of actions and candidates for introductions to overcome new invader were taking into considerations.

Only few animals are known to feed on *M.leidyi* , foremost of which are the **scyphomedusan *Chysaora quinquecirrha***, the **ctenophore *Beroe ovata***, two **harvest fish, *Peprilus alepidotus*** and **butterfish *Peprilus triacanthus*** (Harbison, 1993; GESAMP, 1997).

Chrysaora quinquecirrha - scyphomedusae is one of the main predator of *M.leidyi* in north American waters. It has strict seasonal development. It first appear in May or June in the tributaries of the mesohaline region of Chesapeake Bay when temperatures exceed 17^0 C, and about a month later in the mainstem of the bay. Polyps and medusae of *C. quinquecirrha* are found in Chesapeake Bay at salinities above 5 and below 25 (Purcell et al., 1994, 1999). Abundances of *M.leidyi* and *C. quinquecirrha* medusae have been shown to vary inversely in tributaries of Chesapeake Bay (Purcell & Cowan, 1995). Ctenophores in the tributaries are numerous in spring before the medusae are large or abundant, then decrease or disappear when medusae become numerous, and rebound when the medusae die in the autumn. Predation rates on ctenophores by medusae were sufficient to eliminate ctenophores from the tributaries, where medusae were abundant, but not in the main bay, where medusae were less abundant (Purcell & Cowan, 1995). Densities and biomasses of medusae and ctenophores also vary inversely in the mainstem Chesapeake Bay.

The outcome of interactions between *M.leidyi* and *C. quinquecirrha* depend on the relative sizes of the predator and prey. Predation begins early in the life histories, when ephyrae consume larval ctenophores at higher rates than protozoan of crustacean zooplankton. Ephyrae and small medusae (1 to 23 mm diameter) consumed whole ctenophores that were less or equal in length to the diameter of the medusa, and ate part of ctenophores that were larger (Purcell & Cowan, 1995). Larger ctenophores (25 to 85 mm long) escaped in 97% of free-swimming encounters with medusae 30 to 150 mm in diameter (Purcell et al., 2001).

Thus, first medusa *C. Quinquecirrha* does not always overcome population of *M.leidyi* because it consumes mainly small size of *M.leidyi* and second, the most important, *C. quinquecirrha* is a dangerous animal for people.

Among fish the **harvest fish, *Peprilus alepidotus*** and **butterfish *Peprilus triacanthus***, are predators on *M.leidyi*, the latter appearing to be nutritionally adequate for juvenile butterfish, insofar as the carbon requirement is concerned (Harbison,1993; GESAMP, 1997).

In Narragansett Bay, for example, the butterfish does occur, and may be primary predator on *Mnemiopsis*. This predator accounts for the local late summer – early fall decline of *M.leidyi* (Deason and Smayda, 1982; Kreps, et al., 1997).

Harvestfish, *Peprilus alepidotus* (Linneus, 1766), and butterfish *P. triacanthus* (Peck, 1804), because of the low salinities in much of Chesapeake Bay (5-7‰), they are found mostly in the southern bay and that butterfish could eat 4 to 184 ml ctenophore h^{-1} g fish DW^{-1}, and that this predation probably accounts for the autumn decline of the *Mnemiopsis* population in Narragansett Bay. No estimates of fish predation on *Mnemiopsis* exist elsewhere (11-15‰) (Purcell et al., 2001).

Thus these both species can eat *M.leidyi* but they are subtropical- temperate coastal species, endemic of North America. They did not record in low salinity of the Chesapeake Bay, although in experiments *P. triacanthus* lived two weeks in salinity 4 ‰. Among the disadvantages of the introduction are the facts that its reproductive biology is poorly known, its eggs and larvae may be vulnerable to predation by *M.leidyi* (GEZAMP,1997) and their introduction would be very expensive transcontinental measurements.

We may mention also **the vermform larval sea anemone *Edwardsia leidyi***, frequently infects *M.leidyi* (Crowell, 1976). It is unknown to what extent this endobiont is parasitic. Infected ctenophores often are as vigorous as uninfected ones.

Anemone could not live in the low salinity and although **tissue damage results, *M.leidyi* can regenerate tissue.**

Thus, the food web involving *M.leidyi* seems to be relatively simple based on available information. Only few predators identified to date are a very significant feature. Moreover, the distributional and/or seasonal ranges of occurrence for *M.leidyi* and its predators frequently do not overlap. In Barnegat Bay potential predators (medusae, ctenophores and fish) on *M.leidyi* are seasonally asynchrony in occurrence (GEZAMP, 1997).

Therefore the only invertebrate predator that might be proposed as a biocontrol agent is a species of *Beroe ovata* endemic to the eastern seaboard of the Americas. This species is found in estuaries in both North and South America and is often closely associated with populations of *M.leidyi* and create feedback predator-prey (GEZAMP, 1997).

The species of *Beroe ovata* has two outstanding advantages: firstly, it is highly specific in its feeding, so that even its larval stage feeds on *M.leidyi*. Secondly, its reproductive rate and fecundity are almost as great as that of *M.leidyi*, so that its population can grow at similar rates to its prey (Shiganova et al.,2004a).

Interannual variation in abundance of *Mnemiopsis* is strongly related to predator abundance in U. S. waters. For instance as P. Kremer reported the population abundance in Narragansett Bay decreased dramatically in September, 1974 with increasing numbers of the ctenophore predator, *Beroe ovata* (Kremer, 1976).

There is also much optimism, therefore, about accidental arrival in the Black Sea of another ctenophore *Beroe ovata*, which preys exclusively on zooplanktivorous ctenophores and could be a successful biocontrol of the *M. leidyi* population as shown by the example of the Black Sea ecosystem.

B.ovata was introduced into the Black Sea in 1997, established and spread around the total sea in 1999. *B.ovata* occurres in the areas with salininy 12- 22‰ in the Black Sea Since 1999 *Beroe ovata* spread to the Sea of Azov, where average salinty is 11‰ and lower (Shiganova et al.,2000). Pattern of its development in the Sea of Azov is similar to pattern of *M.leidyi* ones: it may arrive every year after development *B.ovata* population in the Black Sea and survive until temperatute drops in late autumn (Mirsoyan et al., 2006). In 2000 *B.ovata* dispersed also into the Sea of Marmara (Isinibilir et al., 2004) and in 2004 it was found in agregations of *M.leidyi* in the Aegean Sea (Shiganova et al., 2007).

5. Characteristics of *Beroe ovata*, and its role in recovering of the Black Sea ecosystem

5.1. Introduction

Representatives of *Beroe* live in the shallows and estuaries of the Mediterranean Sea, and of the tropical and temperate Pacific and Atlantic Oceans. Few species inhabit Arctic Seas (Mayer, 1912; Chun, 1880; Treguboff and Rose,1957; Greve et al., 1976; Harbison et al., 1978; Seravin, 1998). All species of beroids are considered to be exclusively feeding on other planktivorous ctenophores; some also consume salps. There is often a trophic linkage between *Beroe* species and planktivorous ctenophores. As a rule *Beroe ovata* and *Mnemiopsis leidyi* form a pair; another such pair is constituted by *Beroe cucumis* and *Bolinopsis infundibulum* (a second lobate planktivorous species) (Greve, 1970; Kamshilov, 1960). Representatives of *Beroe* in their turn serve as food for fish such cod, herring and mackerel (Kamshilov, 1960).

Beroe is an important link in pelagic food webs, but before its arrival in the Black Sea, comparatively little was known about its biology. *Beroe* significantly affects the population structure of planktivorous ctenophores and thus indirectly modifies the population dynamics of the zooplankton at lower trophic levels. The example demonstrated by *Beroe ovata* in the Black Sea after its arrival and development there is pertinent in this respect.

5.2.Taxonomy of *Beroe ovata*

With the appearance of a *Beroe* in the Black Sea, the question of its taxonomic identity was relevant. Some scientists of Black Sea countries first identified it as *Beroe cucumis* (Zaitzev, 1998) introduced with ballast waters from arctic seas, others as *Beroe ovata*, suspecting it arrived from the Mediterranean (Konsulov & Kamburska, 1998, Shiganova et al., 2000). A closer analysis of its morphology, including ratio of width and length, and the constitution of its meridian canals led to a revision of its identity, which turned out to be *Beroe ovata sensu* Mayer 1912. It is believed to have been introduced with ship ballast water. Its origin is presumed to be the Atlantic coast of North America, exactly as the previous invader *Mnemiopsis leidyi* (Seravin et al., 2002). Their identifications were supported by genetic analyses (Bayha et al., 2004)

5.3. Morphology

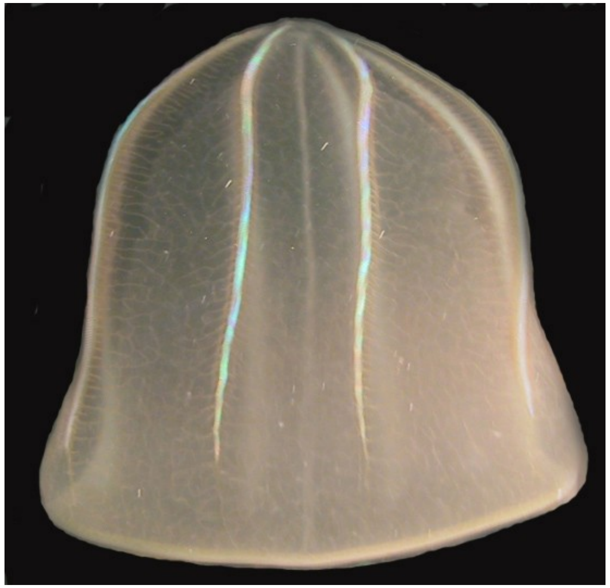

Fig. 22. *Beroe ovata* from the Black Sea (photo of Shiganova T.)

L. Agassiz (1860) regarded the Beroidae as the simplest ctenophores. The loss of tentacles in the Beroidae may have come about, according to Chun (1880), through the powerful development of the cilia, giving freedom and rapidity of motion, and through the great development of a wide-flaring mouth which enables the animal to obtain food without depending on tentacles to capture prey. It is remarkable that no trace of tentacles appears even in the larvae of Beroidae. These ctenophores generally have a pink colour, with largest adults coloured more intensely with a brown tinge. The size of large specimens in the Black Sea is from 81 to a maximum of 162 mm with mean 60-80 mm.

The body is mitten-shaped, wider at the oral end and not tapered at the aboral end; with a ratio of length to width (*l/n*) of 1.1. Lateral compression of the body marked (Fig. 22). Young specimens wider at the oral and aboral ends of the body (Seravin et al, 2002).

The mouth opening is wide and the ectodermal portion of the stomach (stomodeum) is voluminous. The polar- plate surrounding the sense organ at the aboral pole is fringed with a row branched papillae. There are ciliated areas upon the walls of the stomodeum near the mouth. The axial funnel-tube which extends upward to the sense-organ, is deeply cleft so that 2 lateral vessels extend upward to the 2 apical excretion-pores on the sides of the pole-plate; 8 meridional canals and 2 paragastal canals. The meridional canals lie under the 8 rows of ciliary combs; the 2 paragastal canals extend down the middle of the broad sides of the animal and 8 meridian canals may be placed in communication one with another by means an anostomosing network of side branches, thus establish a circum oral canal system, which are characteristic for *Beroe ovata* (Mayer, 1912; Seravin et al, 2002). While studying live Black Sea ctenophores, it was found that both sides the lateral tubes of the meridional canals can anostomose with each other and with the paragastral canals, which do not have own diverticuli. In accordance with these features the new ctenophore of the Black Sea was considered to have originated from the Atlantic northern American coast.

5.4 Eco-physiological characteristics of *Beroe ovata* in the Black Sea

5.4.1. Feeding *B.ovata* in the Black Sea

Beroe ovata is a specialized carnivore of other plankton-eating ctenophores such as *Mnemiopsis leidyi*, *Pleurobrachia pileus, Bolinopsis infundibulum, B.vitrea or Leucothea multicorni.* Some feed on salps (Fraser, 1962; Bishop, 1967; Swanberg, 1974). Among these prey species, only *Mnemiosis leidyi* and *Pleurobrachia pileus* are available in the Black Sea, first and foremost *Mnemiosis leidyi,* which, like *Beroe,* inhabits the upper water layer, above the thermocline (Shiganova et al., 2000, 2001b; 2004a, Finenko et al., 2001)

5.4.2. Feeding behavior *B.ovata* in the Black Sea

In situ observations in the coastal area of the Black Sea showed *B.ovata* to swim near the surface when not feeding. Most of the time it orients vertically, most often with closed mouth; less often it was found deeper, with the body oriented horizontally or almost horizontally.

Feeding individuals of *B. ovata* swallow *M. leidyi* in two ways: enveloping them gradually while opening the mouth widely, and rapidly sucking in the entire prey. Alternatively, they bite off pieces of *M.leidyi* with their macrocillia, but only if the prey is large. *B. ovata* ingests *M. leidyi* individuals over half its own size by seizing and engulfing or gradually enveloping large prey and swallowing it whole (Fig. 23).

Fig.23. *B. ovata* with *M.leidyi* in stomadeum (Photo A.Kideys)

5.4.3. Can *Beroe ovata* feed on prey other than ctenophores in the Black Sea?

Attempts of *B. ovata* to swallow prey other than ctenophores were observed in the Black Sea in first year of Beroe ovata development in the Black Sea (Shiganova et al.,2001b). An individual of *B. ovata* caught with a freshly swallowed medusa *Aurelia aurita* was placed in an aquarium. The *Aurelia* (size 32 mm) was alive inside the *B. ovata* (size 80 mm) stomodeum and continued to make swimming movements. The mouth of *B. ovata* was closed and it kept the medusa in for 8 h before it was ejected. Medusa survived and swam away. Several times, specimens of *Beroe* were seen to envelop other *B. ovata* in aquarium conditions, but the swallowed specimen was invariably egested again (Shiganova et al., 2001b).

It was also observed that *B. ovata* did not consume the copepod *Acartia clausi* and fish larvae*;* if occasionally swallowed, it egested them live through the mouth.

In one experiment, *B. ovata* swallowed two *Pleurobrachia pileus*, which had *Calanus euxinus* individuals in their stomodeum. *P. pileus* was digested but the copepod was rejected through the mouth (Shiganova et al.,2000; 2001b).

5.4.4. Ingestion rate of *B.ovata* in the Black Sea

Feeding rate was measured in experiments in order to estimate *B. ovata* effects on M.leidyi population in the natural conditions. Perhaps the most significant aspect of feeding behavior is that, over an extremely wide range of prey concentration, their ingestion rate is proportional to *B. ovata* concentration. Finenko et al. (2001) found that *B.ovata* normally consumes only one (big) prey at a time. The duration between complete digestion and a new ingestion averages 2.3 h. In Black Sea water and in aquarium conditions, Shiganova et al. (2001b) found that *B.ovata* is capable of ingesting several small preys simultaneously: three *Pleurobrachia* or two *Pleurobrachia* and one small *M.leidyi*. Usually the duration between ingestions varied from 1 to 5 hours.

5.4. 5. Digestion time of *B.ovata* in the Black Sea

Beroe ovata feeds as often as its digestion and the availability of prey allow. During digestion the prey disintegrates in the pharynx, and distributes throughout the gastrovascular canals of the predator, where prey is gradually macerated and pushed by stomodeum cilia to the aboral pole where it accumulates as whitish clumps near the preinfundibular complex. This whitish material enters the preinfundibulum in fractions and passes to the meridional canals. Its remains are excreted through the pores (Shiganova et al., 2001b).

The digestion of *M .leidyi* by *B. ovata* varies from 4 to 5.5 h at a temperature of 21-26^{0}C, depending on predator and prey size. *P.pileus* digestion took 7-8 h at 25^{0}C. Digestion time tended to decrease with increasing temperature (Shiganova et al., 2001b). Finenko et al.(2001) estimated digestion times for *B. ovata* feeding on *M.leidyi* from 0.5 to 5.5 h at 21 ± 1^{0}C. They calculated that the ratio between prey and predator weight (P range 0.01- <2) affected digestion time (D). The relationship between these values is expressed by

$D = 4.26. P^{0.478}$ (n = 19, r = + 0.65) (Finenko et al., 2001).

5.4.6. Daily ration of *B.ovata* in the Black Sea

Daily ration was estimated in two ways (Shiganova et al. , 2001b). First, the cost of respiration at 24-26° C equaled 2.4 cal.h^{-1} g^{-1} of dry weight. Consequently the minimal daily ration of *B. ovata* (assimilation rate 0.7) would be about 80 cal.day^{-1} g^{-1} of dry weight or about 2 cal.day^{-1} g^{-1} of wet weight. Feeding on *M. leidyi* (caloricity 10 cal.g^{-1} wet weight (Vinogradov et al., 1989), the minimal daily ration of *B. ovata* should be about 20% of wet weight.

Second, if *B. ovata* were assumed to feed continuously on *M. leidyi*, one at a time, the digestion time measurements suggest that the daily rations of *B. ovata* would range from 80 to 400% measured as wet weight of both predator *B. ovata* and prey *M. leidyi*. Such rates are unlikely *in situ*.

Observations *in situ* in August-September 1999 indicated that approximately 20% of *B. ovata* had *M. leidyi* in their guts. Therefore, it is estimated that during this period, daily ration of *B. ovata* was in the range of 16-80 % of its wet weight (Shiganova et al., 2001b). The maximum potential daily ration of *B.ovata* in the field in September-October in Sevastopol Bay was calculated using digestion times from the equation, *M. leidyi/B. ovata* weight ratio and mean weight of *M. leidyi*. Since the duration between complete digestion and commencement of new feeding was on average 2.3 h in experiments, the number of meals would be 24 / (2.3 + D) in a day. It follows that daily rations (C in g WW $ind^{-1} d^{-1}$) of *B. ovata* calculated as C 24W / (2.3 + D), where W and D represent the highest weight (g) of *M. leidyi* consumed and digestion time (h), respectively, ranged from 2.2 to 17.7 $g.ind^{-1}d^{-1}$ or 20 to 107 % of its wet weight (WW).

5.4.7. Reproduction *B.ovata* in the Black Sea

Beroe ovata like *Mnemiopsis leidyi* and most ctenophores, is a hermaphrodite (Mayer,1912). Male and female gametes and their state of maturity are visible in adult specimens by observing the gonads. Adult specimens have mature testicles and ovaries, but sperm is released first. Thereafter, eggs (10-60 at the time) are slowly extruded. Sperm is emitted through sperm-ducts situated at the edge of the eight rows of comb plates. The shedding lasts for several minutes. During this period the beating of comb rows ceases and then resumes, thereby dispersing the spermatozoids. The laying of eggs follows through separate gonopores. When kept on a normal daylight rhythm, animals seem to shed gametes without any predictable periodicity about once a day or every 2 days for up to 2 weeks. If they are kept in the dark for long periods (48-72 h), spawning can be induced in most mature animals within 2-3 h of exposure to bright sunlight (Shiganova et al.,2000).

5.4.8.1. Fecundity *B.ovata* in the Black Sea

Black Sea *B.ovata* start to reproduce when it reaches slightly over 30mm; its fecundity increases with growth, and varies from 2000 to 7000 eggs per day. Egg production increases with body length from 4- 40 eggs per day in small specimens to 5000-7000 eggs per day in specimens of 80-120 mm in length. Egg production also depends on the amount of food ingested (Arashkevich et al., 2001; Shiganova et al, 2003).

5.4.8.2. Development of *B.ovata* in the Black Sea

The freshly spawned egg is surrounded by a reflective meshwork, which disappears in the first hour after shedding, while a thick gelatinous layer swells around the egg. Maturation divisions and the formation of the outer envelopes are independent of fertilization. The egg pronucleus remains in the cortex below the polar bodies. The unfertilized egg has a glass-like appearance.

When several animals are kept in culture together, eggs are fertilized immediately upon release. The eggs of animals kept in isolation are usually not fertilized although cases of self-fertilization have been observed and it was observed in the Black Sea (Shiganova, 2000). One or several spermatozoa enter the *Beroe* egg (Yatsu, 1911) and gamete fusion and incorporation of the sperm head are accomplished in less than 1 min. During this time fragellar beating stops and the tail stands erect. Thereafter, the cortex around the sperm nucleus becomes differentiated.

Embryogenesis is rapid and highly stereotyped. Hatched larvae are beroid, without tentacles.

5.4.7. Predatory impact of *B. ovata* on *M.leidyi* in the Black Sea

Predatory impact of *B. ovata* on *M. leidyi* in the north-east and northwest Black Sea (Sevastopol Bay) (Shiganova et al., 2001b; Finenko et al., 2001) was estimated from biomass data of both ctenophores and maximum daily rations. In September 1999, *B.ovata* consumed 9.3% and in October

132% of available *M. leidyi* biomass. *B. ovata* biomass in October was in 10 times higher than that in September. These values should be considered as maximum values, under continuous feeding and with food constantly available.

In the Blue Bay, this value was 20% in 1999 (Shiganova et al., 2000). In 2000 and 2001 *M.leidyi* population (Shiganova et al., 2003b) reached a high density by mid-August before the appearance of *B. ovata* due to high water temperature. But with development of *B .ovata*, *M. leidyi* decreased from 2400 $g.m^{-2}$ in late August to 700 $g.m^{-2}$ in two weeks and 380 $g.m^{-2}$ in the next 10 days (mid September). Thus, with rich prey availability, *B. ovata* increased population size by a factor 11 during September. Intensity of reproduction was high (Shiganova et al., 2003), but with decreasing *M. leidyi* availability, *B. ovata* density rapidly began to fall as well. The number of eggs decreased to zero in November (Arashkevich et al., 2001) and the population disappeared from the northeastern Black Sea by the end of November. The time of decrease reproduction rate of *B.ovata* may occur earlier in condition of absence preys (Shiganova et al, 2001b).

We conclude that *B.ovata* effectively controls *M.leidyi* population size; it responds by an increase in numbers at high *M.leidyi* availability and maintains a high predation rate as long as prey is abundant. At decreasing *M.leidyi* consentration, *B.ovata* gradually stops reproducing and finally disappears from water column.

5.5. Seasonal pattern of *B.ovata* in the Black Sea

Beroe ovata was first recorded in the north-west Black Sea in 1997. During 1997-1998 it occurred in some coastal areas in the northern Black Sea (Konsulov & Kamburska, 1998). By late August 1999, it had spread throughout the northeastern Black Sea (Shiganova et al., 2000) and was found in the northwestern and southern regions (Finenko et al., 2000; Finenko et al, 2001). In October 1999, it was first observed in the Sea of Azov (Shiganova et al., 2000).

The twelve years of observations showed roughly the same seasonal pattern. First individuals appear from the July to late August-early September. As a rule *Beroe* development follows the peak of *M. leidyi* reproduction in approximately one or two weeks. Soon after the appearance of *B. ovata*, it started to reproduce and, 10--14 days later, its reproduction reached its peak. *B.ovata* development peaks in late August – September and its population decreases with disappearance *M. leidyi*. By the end of November –early December, both ctenophores disappears, only few individuals of M.leidyi can be found in water column.

The phenology of both ctenophores differs between years, and so does their peak development and reproduction. It is probably affected, first, by the concentrations of zooplankton, the food required for the development of *M.leidyi.* Thus, there is a cascading effect from zooplankton to *M.leidyi* to *B.ovata.* A second factor is water temperature in the surface layer. The interannual variations in abundance of *B. ovata* (taken at the peak of its development in September), as well as those of *M.leidyi* (taken in August before the development of *B. ovata)* correlate with mean summer water temperature and with one another (Shiganova, 2009).

Little is known about where and how *Beroe ovata* specimens spend winter, spring and early summer in the Black Sea or elsewhere across its range. Probably, some individuals survive in lethargy near the bottom at depths where no hydrogen sulphide occurs. Overwintering in deep water layers has been reported in the Canadian Arctic (Siferd & Conover, 1992). According to Falkenhaug, dense winter samples of *Beroe cucumis* were obtained when a MOCNESS accidentally touched the bottom. Populations located close to the bottom may be commoner than believed, but difficult to catch with traditional sampling gear (Falkenhaug, 1996).

After development population of *Beroe ovata* in the Black Sea ecosystem began to recover at all levels including fish stocks, but there are interannual variations in abundance of *M.leidyi* and *B. ovata* consequently, which depend on temperature and food (zooplankton) concentration. After warm winter in high zooplankton concentration *M.leidyi* may reach high value before seasonal development of *B.ovata* and greatly decreased zoo-, mero- and ichthyiplankton abundance, but with development *B.ovata, M.leidyi* abundance sharply dropps and its effect minimizes. So, we may conclude that even now after appearance B.ovata there is M.leidyi effect on ecosystem in more or less degree but anyway it lasts much shoter not more than two months enstead of 8-10 months as it had been before B.ovata arrival.

Summarizing, we find that top-down control existed before *M. leidyi* by predators such as dolphins and fish-eating fish, on planktivorous fish, on zooplankton, and down to phytoplankton and from microplankton to detritus. All this was deeply modified by *M. leidyi*, but gradually began to recover with *Beroe* ovata invasion. Their outbreaks have significantly advanced our understanding of the complex nature of the role of invasive gelatinous species in (coastal) marine ecosystems. It offers an example of how lower gelatinous animals can affect a whole system: one of them completely suppressed a productive ecosystem, while the other recovered it. These events should be taken advantage of. An immediate example that comes to mind is that of the unique resources of the Caspian Sea, now threatened by *M. leidyi* and in urgent need of biological rescue (Shiganova et al.,2004).

6. Experiments on possibility introduction of Beroe ovata into the Caspian Sea .

Riparian countries of the Caspian Sea have been evaluating the pros and cons of the predatory ctenophore *Beroe ovata* as a biocontrol agent against the invasive ctenophore *M.leidyi*. To assess the viability of *B.ovata* establishment in the Caspian Sea, the survival and the main physiological characteristics (feeding, respiration,reproduction and growth) of B.ovata were studied in the Caspian Sea water (12.6‰ salinity) conditions using animals transported from the Black Sea (Kideys et al,2004).

6. 1. Laboratory studies on physiological characteristics of *Beroe ovata* in the Caspian water

First experiments on survival of *B.ovata* in Caspian Sea water (12.6 ‰salinity) and on physiological characteristics such as feeding, respiration, reproduction and growth were performed in Khazerabad laboratory (Mazandaran) on the Caspian coast of Iran by Ahmet Kideys (Institute of Marine Sciences, Erdemli, Turkey)**,** Galina Finenko, Boris Aninsky (Institute of Biology of the Southern Seas, Sevastopol, Ukraine)**,** Tamara Shiganova (P.P. Shirshov Institute of Oceanology RAS, Moscow, Russia)**,** A. Roohi, Mojgan. Tabari, M. Youseffyan, and M. T. Rostamian, (Mazandaran Fisheries Research Center, Sari, Iran).

B.ovata, generally small individuals (10-40 mm), was transported to the Caspian coast of Iran in two batches. For the first batch, thirty *B.ovata* sampled from Sinop, Turkey (southern Black Sea; salinity about 18 ‰) were transported to the laboratory in Khazerabad (Mazandaran, Iran) in a 10 l jar. Seven individuals were kept individually at 26^{o}C at their original salinity in 5-1 containers during 1 day. The next day they were moved to a salinity of 16 ‰, and a day later to a container with Caspian water (12-13 ‰).

A second batch about 60 individuals *B.ovata* were collected from the Bosphorus (salinity around 22 ‰). Upon arriving to the laboratory healthy looking specimens of *B.ovata* were put into a 15 l large tank in a room at 21^{0}C.

6.1.1. Acclimation to the Caspian Sea water salinity.

Acclimation of Black Sea *B.ovata* to Caspian water was done by decreasing salinity step by step from 22 ppt to 12.6 ‰. After 4 hours, salinity was diluted to 17.4 ppt using filtered Caspian water (12.6 ppt off Khazerabad). During the next days, salinity was further decreased every 9-17 hours to 15.0, 13.5 and finally 12.6 ‰ and the behavior of animals observed.

Upon changing salinity from 22 to 17.4 ‰, animals first gathered near the bottom. Some specimens of *B.ovata* stopped cilia beating. After 20 minutes almost all specimens were active again. In the next 10-30 min, they were swimming and already had *M.leidyi* in their stomachs. They remained in normal condition upon consecutive transfers to 17.4, 15.2, 13.5, to 12.9 ‰ and did not show behavioral changes. Each 15-30 min after a transfer, most specimens resumed swimming and feeding on *M.leidyi*.

The animals that were transferred from 18 ‰ (at Sinop, Anatolia) to 16 ppt and then to Caspian water did not stop cilia beating and continued to feed and swim as in Black Sea water.

All containers were aerated. After acclimation to the salinity of the Caspian Sea, the experiments on feeding, respiration, growth and reproduction rates were set up.

6.2 Eco-physiological characteristics (feeding, respiration, growth and reproduction rates) in Caspian water as a prerequisite to a possible introduction into the Caspian Sea

6.2.1. Estimation of ingestion rate, digestion time and ration

To determine the feeding rate of *B. ovata*, two series of experiments at 21° C were conducted. In the first series in each of 15 containers (3.5 1iter capacity each) 12 *M.leidyi* of four size groups (<5, 5-10, 11-15 and >15 mm, being 3 *M.leidyi* from each size group) as food for individual

B.ovata were placed. The 16th container contained only *M.leidyi* as a control. The length of *B.ovata* in these experiments ranged from 13 to 35 mm. All *B.ovata* were starved during the 24 hours before the experiment.

In addition to feeding rate, we determined prey-size preference, digestion time as well as intervals between ingestions, monitoring all bottles every 30 min during 24 hours.

B. ovata had abundant available prey and could feed *M.leidyi* over the whole period. Total biomass of prey was about 1.66 ± 0.31 g l^{-1}. The numbers and length of *M.leidyi* in the containers were counted and measured at the beginning and the end of experiment. The daily ingestion rate (number or biomass of prey consumed by one *B.ovata* per day) was calculated from the difference in total numbers at the start and end of observations. To estimate the ration in weight units the relationship between length (L,mm) and wet weight (g) of *M.leidyi* was used: $W = 0.0011*L^{2.34}$ (Kideys et al., 2001). *B.ovata* weight was computed from the length- weight relation $W = 0.0007*L^{2.47}$ (Finenko et al., 2001).

In the first series of short-term feeding experiments, where 4 different size groups of *M.leidyi* were offered to *B.ovata* in equal numbers but different biomass, small *M.leidyi* (3-8 mm) was insignificant part in the daily ration: in *B.ovata* with length <20mm it was 2.58% (n = 6), with length 20-25 mm - 1.23% (n = 5) and in the largest *B.ovata* >25 mm it was 3.7% (n = 4). *B.ovata* thus preferred large and medium sized *M.leidyi* to meet its food requirements. The daily rations were high; they ranged from 45 to 765 % of body weight and were highest in small (13-16 mm) *B.ovata*.

The second series of feeding experiments were conducted to determine ration value at different prey sizes (3 size groups: I -5-6 mm, II-10 mm and III - 30-40 mm *M.leidyi*) in the same biomass concentration (about 1 g l^{-1}). This special series of feeding experiments also aimed to determine digestion time with respect to the size ratio of prey and predator. Once ingestion occurred the *B. ovata* specimens were monitored every 15 min until defecation was completed and the gut was empty.

A long-term experiment (14 days) to study feeding and growth rates was performed at 25±1^{0} C as well. Five *B.ovata* with initial wet weight 3.17 –4.64 g (length 30-35 mm) were placed individually in containers (4.2-17.0 l volume) to which 5 to 15 *M.leidyi* (size 10 –30 mm) were added to a concentration of about 1 ind l $^{-1}$. The number of *M. leidyi* in the containers was counted daily and new prey was added to maintain initial prey concentration. Daily ration was estimated from the difference in number and wet weight of prey at the beginning and end of each day.

In the second series of feeding experiments *M. leidyi* of different size was offered to *B.ovata* in the same biomass concentration (about 1 g l $^{-1}$) but different number, separately. The maximum daily rations of *B.ovata* were observed when they consumed large *M.leidyi*, but they could ingest intensively the small *M.leidyi* too and specific daily rations were very close for different sized *M.leidyi* (Table 5; Fig.23).

Table 5. Daily ration (g ind $^{-1}$ day^{-1}) and weight-specific daily ration (%) of *B.ovata* feeding on different sizes of *M.leidyi* .

B.ovata length, mm	*M.leidyi* length, mm	Number of *Mnemiopsis*. per jar	Ration, g ind^{-1}day^{-1}	Weight - specific daily ration, %	N
9 – 30	5	50	0.51 - 1.73	13.7 – 267.0	12
10-32	10	10	0.35 - 2.49	28.8-162.0	14
20-35	20-40	3	1.22-6.17	25.2-238.0	8

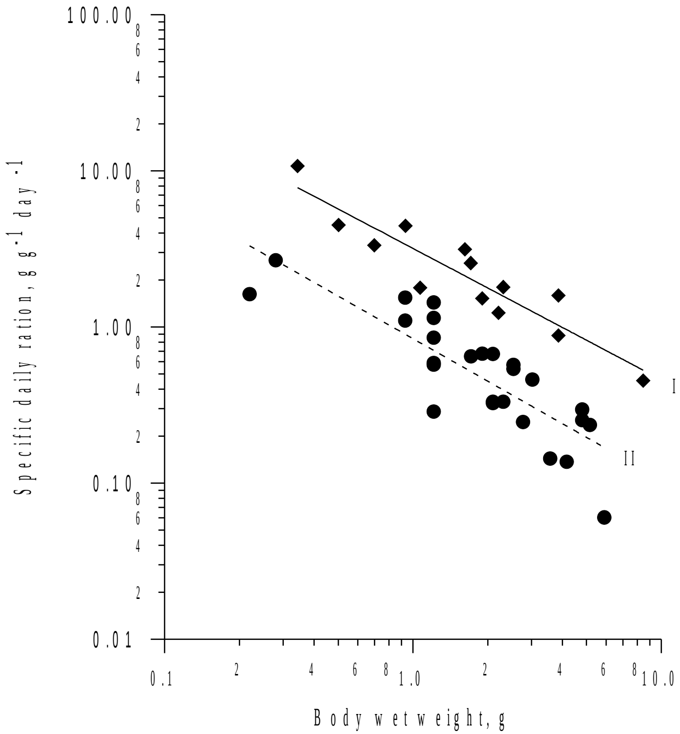

Fig. 24. Effect of body weight on specific daily ration in *Beroe ovata* at 1.66 g l^{-1} (I) and 1.0 g l^{-1} (II) food concentration

The relationship between specific daily ration (C, g $g^{-1}day^{-1}$) and *B.ovata* wet weight at two food concentrations (I- 1.6; II- 1.0 g l^{-1}) is described by two power functions:

I. $C = 3.184\ W^{-0.841}$ $r^2 = 0.852$

II. $C = 0.842\ W^{-0.904}$ $r^2 = 0.701$

The difference between specific daily rations at tested food conditions showed that food concentration is an important factor in *B.ovata* feeding.

Digestion time of *B. ovata* feeding on *M. leidyi* at 21±1^{0}C was variable and ranged from 30 to 450 min in the studied length range of both ctenophores (13-38 mm in *B.ovata* and 3-27 mm in *M.leidyi*). In one case we observed a digestion time as long as 650 min in a *B.ovata* with length 13 mm which digested at once 2 specimens *M.leidyi* of 26 and 15 mm length. Interval between two consecutive meals ranged from 95 to 720 min (1.5 - 12 h) but in one case (22 mm *B.ovata*) it was 1240 min. Average digestion time at 21 ^{0}C was 210.15 ± 156.9 min, and interval between 2 meals was 363.75 ± 311.47 min. Digestion time at 26^{0}C varied from 55 to 318 min in *B.ovata* and *M.leidyi* length range of 18-42 mm and 10-20 mm accordingly with average 99±57 min. Every size of *B.ovata* consumed both small and large *M. leidyi*; but the ratio between prey and predator weight (P) in these experiments had no significant effect on digestion time (D, min). The relation between these values is expressed by :

21^{0}C: $D = 249.4\ P^{0.3}$ $r^2 = 0.52$ (for a P range of 0.003 -5.38).

26 ^{0}C: $D = 174.86\ P^{0.17}$ $r^2 = 018$ (for a P range of 0.03-5.28).

Digestion time at 21^{0}C was probably overestimated; because of the long period between two observations (30 min) some predation acts could have been missed (Fig.25).

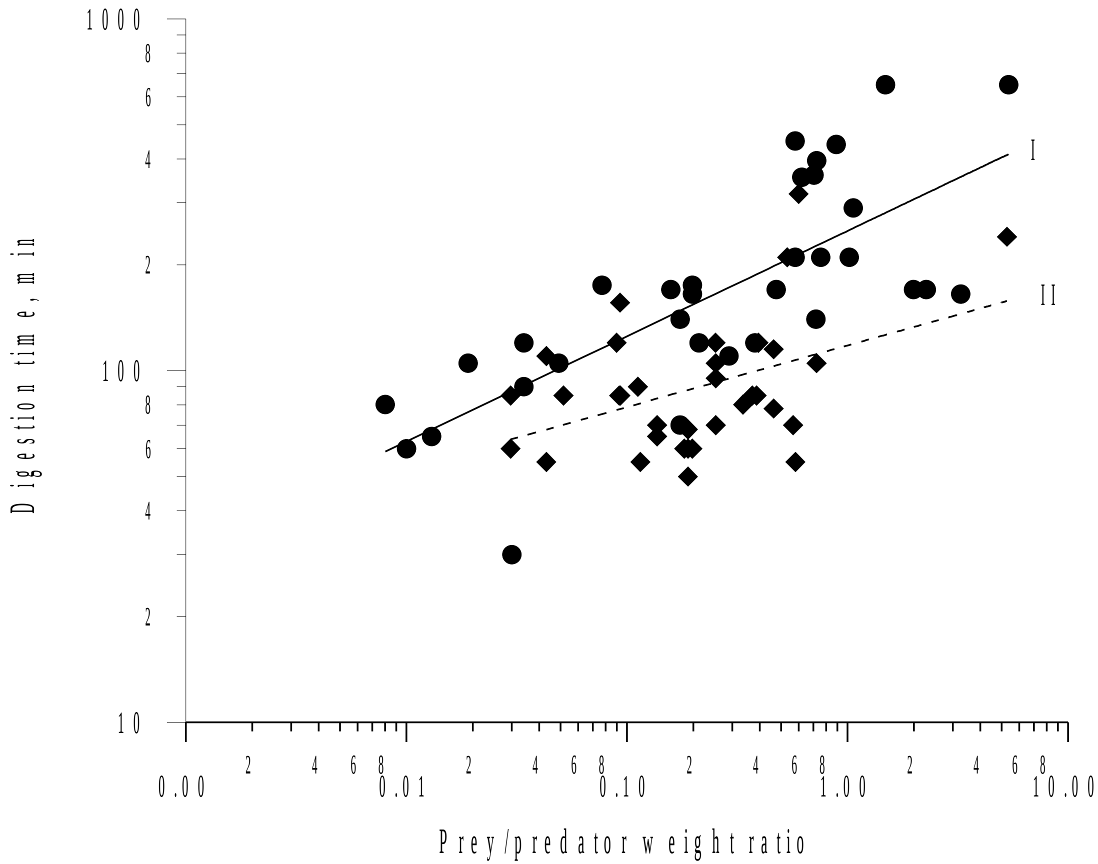

Fig. 25. Effect of prey/predator weight ratio (P) on digestion time (D) in *Beroe ovata* in Caspian water at 21^{0}C (I) and 26ºC (II)

6.2.2. Ingestion rate in long-term experiments

The rations in these experiments were obtained for ctenophores fed under unlimited prey availability. According to these data, periods of intensive feeding alternated with periods of decreased feeding. Mean daily ration of *B.ovata* with initial weight 3.17-4.6 g in long-term experiment amounted 26-43% of body weight.

6.2.3. Respiration rate

The relationship between oxygen consumption rate (R, ml O_2 ind $^{-1}$ h $^{-1}$) and wet weight of *B. ovata* (g) at 21-23 ^{0} C (Fig.25) :

$$R = 0.0052\ W^{1.02} \qquad (r^2 = 0.87)$$

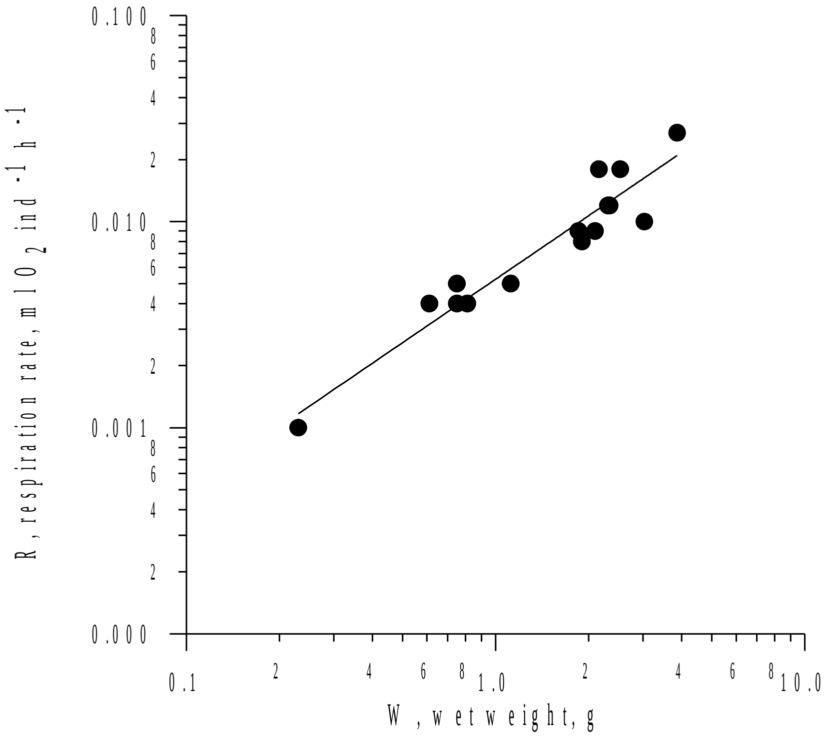

Fig. 26. Relationship between respiration rate (ml O_2 ind $^{-1}$h $^{-1}$) and wet weight (g) of *Beroe ovata* in the Caspian Sea water

The weight - specific coefficient was 1.02, indicating that the weight – specific respiration rate is independent on weight over the measured weight range (0.23-3.87 g).

6.2.4. Reproduction

Aquaria with *B.ovata* were checked every morning with the aim to obtain eggs of *B.ovata*. Eggs and early embryos obtained from specimens of *B.ovata* in aquariums with Caspian water were placed in an incubator or in 100 ml dishes. They were examined every few hours to observe hatching and development of *B.ovata* in the Caspian water.Sixty eggs of *B.ovata* were obtained, thirty of which were incubated.

After 24 hours, 10% of embryos survived in dishes and about 70% in the incubator; after another 24 hours all embryos and larvae were dead.

During the following days from 2 to 27 eggs were obtained from each aquarium with fed *B.ovata* at temperature 21-24^{o} C, in total 78 eggs. Again, the development of the eggs was not successful. Only five larvae, that died after few hours, were obtained. In all, 138 eggs of *B.ovata* were obtained and 7 larvae hatched.

The reasons for low fecundity might be availability only small sized *B.ovata* (10-40 mm) and disturbed ovae of ctenophores (examined and replaced in another dish)very often did not develop in experiments (Greve, 1970, Shiganova et al., 2004b).

6.2.5. Growth rate and energy budget

Growth rate was estimated from regular measurements of *B.ovata* length in each container every day at the same time. *B.ovata* weight was computed as in the feeding experiments.

The energy content of *M.leidyi* specimens was calculated by chemical composition and caloric value of each main biochemical compound determined (i.e. 5.65 cal mg^{-1} for protein, 9.45 cal mg^{-1} for lipid and 4.10 cal mg^{-1} for carbohydrate). All major organic components of tissue (protein, lipid, carbohydrate, amino acids) were quantitatively assayed by colorimetry (Anninsky, 1994).

Of five specimens selected for this experiment (4 of them with initial weight of 3.17 g and one with 4. 64 g) growth of four specimens was recorded.

Average weight for three *B.ovata* of similar initial weight (3.17 g) increased during the experiment and growth could be expressed by (Fig. 27):

$W = 2.615\ e^{0.101\ t}$ $\qquad$ $R^2 = 0.964$,

where W is wet weight, g, t- time, days.

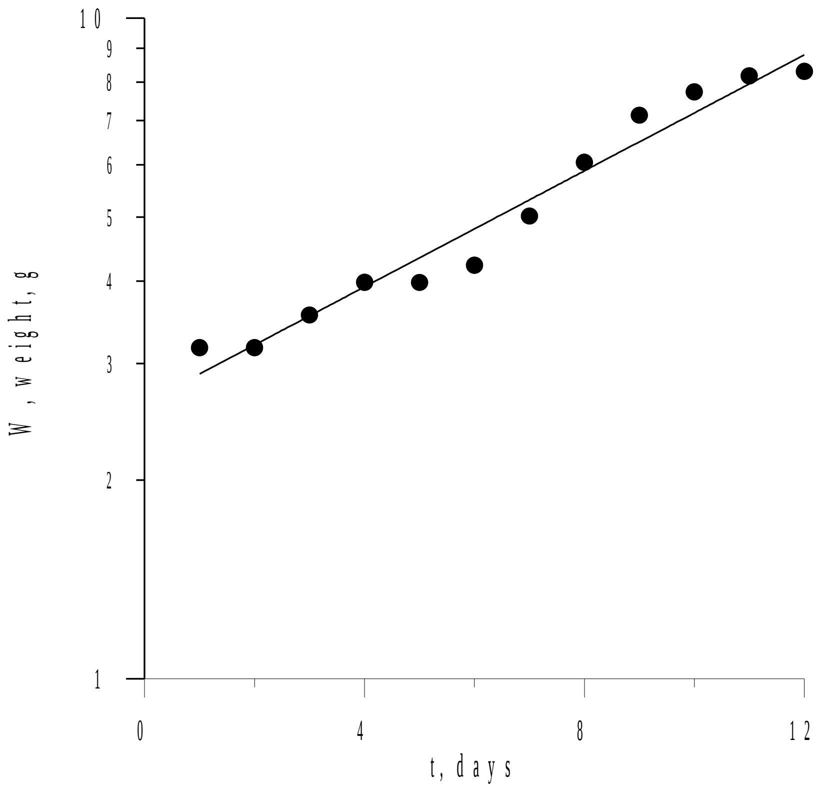

Fig. 27. Weight growth of *Beroe ovata* in the Caspian Sea water

On the basis of food consumption, respiration and growth rates in the long-term experiment, the energy budget of *B. ovata* was calculated (Table 6). Average value of energy content for all size *M.leidyi* from our measurements was 6.8 ± 0.2 cal g^{-1} wet weight and was similar to that in the Black Sea (Anninsky, 1994). We did not measure energy content in *B.ovata* in Caspian water, but because in *M.leidyi* was the same as in the Black Sea we used its Black Sea caloricity (17 cal g^{-1} wet weight, Finenko et al. 2001) to calculate its energy budget.

Table 6. Daily energy budget (cal $ind^{-1} day^{-1}$) of *B.ovata* in a long-term experiment

Initial weight,g	C	R	G	A	A	K_1	K_2
3.17	18.06	4.73	11.27	16	0.88	0.62	0.7
3.17	10.73	2.89	4.1	6.99	0.65	0.38	0.59
3.17	17.11	3.57	7.7	11.27	0.65	0.45	0.68
Average					0.72±0.13	0.48±0.12	0.66±0.06

Where C is daily ration, R is respiration rate, G- growth, A – assimilated food, a is assimilation efficiency, K_1 and K_2 are gross and net growth efficiency.

Mean assimilation efficiency in animals with initial weight of 3.17 g was rather high (0.72 ± 0.1) as well as gross and net growth efficiency (K_1 = 0.48 ± 0.12 and K_2 = 0.66 ± 0.06).

6.3. Experiments on *Beroe ovata* reproduction in 2002.

6.3.1 Reproduction rate of Beoe ovata in different salinity of the Caspian Sea water.

The experiments were conducted by Drs. Shiganova Tamara and Bulgakova Julia (SIORAS) in the Southern branch of SIO RAS near the Blue Bay shore in the Black Sea in September 2002. Experiments were performed in the Caspian Sea water of different salinity, which were brought the scientists of CaspNIIRH under leadership of Dr. A.F.Sokolsky. Simultaneously the same experiments were conducted in the Black Sea water. Experiments showed that *Beroe ovata* could live at salinity 7-8 ‰ , could feed on *M.leidyi* and had normal metabolism rate at salinity 10‰ and could reproduce at the minimal salinity 10‰, but optimal salinity with higher reproduction rate was 11.35‰ and higher . Ovae obtained at this salinity could develop, larvae hatched and continued development in the Caspian Sea water 11.35 – 13.0 ‰ . Experiments also showed that the highest fecundity recorded when ctenophores reaches 50 mm length.

Experiments on feeding, respiration and reproduction were performed simultaneously in the Black and Caspian Sea waters. Feeding rates were approximately the same in the Caspian and Black Sea waters, ration was higher in the Black Sea water. The metabolism rate was higher in the Black Sea water. The optimal salinity according to this experiment was 11-12 ‰ of the Caspian Sea water.

Beroe ovata reproduced at the lowest salinity 10‰ in two aquariums with the Caspian Sea water, optimal salinity was determined as 11.35‰ in 8 aquariums. Fecundity was 8-418 ovae/day. However the low fecundity might be explained that we estimated not first offspring. Individuals of B.ovata were kept for several days in aquariums for acclimatization to Caspian salinity and probably they had already spawn at least one offspring. We have assessed that fecundity was lower with every next offspring in aquariums even in the Black Sea water, particularly sharp decrease was recorded without available prey (Mnemiopsis). In our experiments *M.leidyi* as a food almost was not available during last days experiments when we had acclimated B.ovata to the Caspian Sea water.

6.3.2. Experiments to study tolerance of *Beroe ovata* to environmental parameters

6.3.2.1. Tolerance to salinity

Experiments were conducted with the aim to determine its lowest limit of comfort in salinity. It was determined that *B. ovata* can live in water with salinity lower than in the Black Sea. The behavior of B.ovata individuals remained unchanged to a salinity of 7.3 ‰. Smaller ctenophores were better adapted to decrease salinity (Shiganova et al., 2000; 2001b).

Beginning with a salinity of 7.3 ‰ individuals of *B. ovata* sink to the bottom almost without movements. The body grows turbid, but after 20-30 min. the ctenophore resumes normal movement. At a salinity of 4.5 ‰t, the ctenophore sinks down to the bottom without movements, and its tissue turns whitish, an indication of decomposition. Later, some recovery may occur. However, at a salinity of 3 ‰, *Beroe* remains motionless and dies.

Thus, irreversible processes begin at a salinity of about 7 ‰. These data have showed that ***Beroe ovata* can live in the water with salinity less than in the Black Sea and probably lowest salinity for survival is salinity more than 7** ‰ (Shiganova et al., 2000, 2001b).

6.3.2.2. Tolerance to temperature.

B. ovata was active in the water both Black and Caspian Sea at the temperature 20 °C and higher in our experiments. In the coastal area of the Black Sea *Beroe ovata* had very high reproduction rate in the high water temperature 27-28°C .

Othert experiments have shown that B.ovata could live, fed on and reproduced at temperature lower than 20 °C in the Black and Caspian water in the experiments made by S.P.Volovik team (AzNIIRKH), the lowest temperature in experiments was 9°C when B.ovata could live and feed.

6.3.2.2. Tolerance to oxygen. *Beroe ovata* is more sensitive to oxygen content in the ambient water. Our observations have indicated that threshold is estimated at 1ml/l while for M.leidyi threshold is o0.25 ml/l (Shiganova et al., 2001b).

6.4. Conclusions

Definitely, *B.ovata* can live and grow in Caspian water with minimal salinity 10‰. It can be acclimated to salinity of the Caspian water in only few days. Salinity should be decreased by 1 ‰ for 24 hours gradually by 0.2 ‰ every 4-5 hours for individuals > 50 mm length, salinity could be decreased faster for smaller size *B.ovata* by 1,5-2 ‰ per 24 hours.

After acclimation, individuals of *B. ovata* at 12.6 ‰ and temperature 21^{o}C survived in 12 aquariums for one month (13 September - 9 October) and they were in good state and continue feeding in Iranian experiments.

B. ovata feeding rate at 12.6 ‰ was high and ranged from 14 to 765 % of body wet weight. These values are close to these in the Black Sea *B.ovata* at 18 ppt where daily ration of adult ctenophores at high food abundance ranged from 5% to 460% of wet body weight from the largest to the smallest animals (Finenko et al., 2001; Finenko et al., 2004). All sizes of *B. ovata* ingested small and large prey, so in the Caspian Sea, where most *M. leidyi* are small, they should be able to decrease sharply its abundance.

Digestion time of *B. ovata* in Caspian water ranged from 0.5 to 7.5 h at 21^{0}C and from 0.9 to 5.3 h at 26^{0}C. In Sevastopol Bay (the Black Sea) these values varied from 0.5 to 5.5 h at 21^{0}C (Finenko et al., 2001). Although there was no correlation between digestion time and prey/predator weight ratio in Caspian experiments, we believe in some difference between digestion time in Black Sea and «Caspian» *B. ovata* (at 21^0 C they were 0.003-5.38 and 0.01-< 2 in Caspian and Black Sea ctenophores, accordingly). Comparison of *B. ovata* digestion time at 26^0 C in Caspian water with data for the Black Sea at 21^0 C (Finenko et al., 2001) shows that coefficient Q_{10} amounted 2.3 in this temperature range, in accordance with the general acceleration action of temperature on physiological characteristics of aquatic animals.

B. ovata weight specific respiration rate in the Caspian Sea water was lower than that in the Black Sea (Finenko et al., 2001, Shiganova et al., 2001b), calculated on the basis of wet weight. Dry/wet weight ratio in *B.ovata* is 0.78%, as in *M. leidyi* (Shiganova et al., 2001); values of weight specific respiration rates per unit dry weight are very close (0.63-0.82 and 0.67 ml O_2 g dw^{-1} h^{-1} in Black and Caspian *B. ovata* accordingly). Kremer et al. (1986) found a weight specific respiration rate of *B. ovata* from the Atlantic costal waters of the North America, 2.5 times lower than the figures given here. However, the specific carbon content in *B. ovata* from the Atlantic coastal waters is 2-3 times lower than that for Black Sea ctenophores, and thus the carbon specific respiration rate in *B. ovata* from both regions seems almost the same.

The daily specific growth rate of ctenophores in our study was 0.1 (10%) of body weight. This value was obtained for adult *B. ovata* with initial length of 30 mm when daily ration ranged from 26 to 43% body weight. The same values were characteristics of the Black Sea *B. ovata* in feeding laboratory experiments when ctenophores consumed daily about 50% of their body weight (Finenko et al., 2004). Greve (1970) estimated specific growth rate of juvenile *B. gracilis* of 5-15 mm as high as 0.4 at 16^0 C and Kamshilov (1960a,b) reported 0.02-0.04 in the Barents Sea for adult *B. cucumis*.

All values from the energy budget (assimilation as well as gross and net growth efficiency) in our experiments were high and comparable to these in other ctenophores (Reeve & Walter, 1978; Kremer & Reeve, 1989; Reeve et al., 1989; Finenko & Romanova, 2000). Mean assimilation efficiency in adult ctenophores with initial weight 3.17 g was 0.72 ± 0.1; gross growth efficiency (K_1) equaled 0.48 ± 0.12 and net efficiency (K_2) was 0.66 ± 0.06.

According to these data ***B. ovata*** will be able to live in the Southern and Middle Caspian and probably in the southern boundary of the Northern Caspian, where salinity is not less than 10‰, although it can survive with minimal salinity 7,3‰.

B. ovata will develop at the same season from the middle of August till October – November. The temperature in the Southern and Middle Caspian surface layer is approximately the same that in the Black Sea.

Physiological evidence suggests that in the Caspian Sea water with salinity 10-13‰, *B. ovata* reproduces, grows and ingests *M. leidyi*. Released to the sea, it is therefore expected that it will decrease *Mnemiopsis* abundance sharply.

In future, more additional investigations on reproduction should be done. In experiments 2002 in Gelendgik laboratory showed that *B.ovata* ovae were hatched and larvae were live and developed in salinity not less than 10‰, when experiments were over, the larvae were sent to Dagestan branch of CaspNIIRKH

Even now sum of our knowledge allow us to conclude that *Beroe ovata* will be able to live, feed on M.leidyi in the Caspian Sea, where salinity not less than 7‰ and *B. ovata* can reproduce in the Caspian Sea where salinity not lower than 10‰.

Thus *B.ovata* will be able to control Mnemiopsis population in the most abundant its habitats – in the Middle and Southern Caspian Sea.

6.5. Mesocosm experiment on possibility predation of ctenophore *Beroe ovata* on zooplankton and other preys in addition to ctenophore *M. leidyi*

In 2003 in Iran (Sari, Ecologic institute of Caspian Sea), special experimental mesocosm was performed with investigations on possibility predation of ctenophore *Beroe ovata* on zooplankton and other preys in addition to ctenophore *M. leidyi* in the Caspian Sea. Mesocosm experiments has been performed under leadership of A. Javanshir and T.Shiganova as invited international consulter with participation Fatima Tahami, Fariba Vahedi, Alireza Mirzajani, Maryam Rezaii, Mujgan Tabari, , Abolghassem Roohi (Shiganova et al., 2003). Mesocosm system was developed in order to estimate as many as possible effects *B.ovata* on the tropic webs of Caspian ecosystem and environment. Therefore we include measurements of:

Chemical parameters: O_2 (mg/l) pH, $CaCO_3$, TDS (g/l), Si O_2(mg/l), PO_4(mg/l), NO_3, NO_2, NH_4 (mg/l), EC ms.

Hydrophysical parameters: t ^{0}C, salinity.

Biological parameters: Phytoplankton, Microplankton (bacteria), Zooplankton, Mnemiopsis leidyi, Beroe ovata. Experiment has been designed as shown in table 7.

Table 7. Experimental mesocosm design

	Number of replications	Beroe numbers in tank	Mnemiopsis numbers in tank	Zooplankton consentration in tank
Beroe+ zooplankton	4	**7**		Acartia tonsa Adult +copepodits 79000 Nauplii 2400
Beroe+ mnemiopsis+ zooplankton	**2**	**7**	300	Acartia tonsa Adult +copepodits 79000 Nauplii 2400
Mnemiopsis+ zooplankton	2		300	Acartia tonsa Adult +copepodits 79000 Nauplii 2400
zooplankton	2		300	Acartia tonsa Adult +copepodits 79000 Nauplii 2400
Caspian Sea water	1			

The main focus of our mesocosm was an identification of possibility *B. ovata* individuals to feed zooplankton or other items from the Caspian Sea in addition to *M.leidyi* in condition when *M.leidyi* as a prey is not available. Based on the results of observations, we could conclude that individuals of *B.ovata* in our experiments were in good conditions after acclimation to the Caspian Sea water salinity (12,6‰), they fed on *M.leidyi* and reproduced. Eggs developed and larvae hatched (Table 8).

Table 8. Numbers and size of *Beroe ovata* in experiments

No tank	Contents	Initial numbers of Beroe	Initial size mm	numbers of Beroe ovae and larvae							
				22.09.03		24.09.03		25.09.03		26.09.03	
				ova	larva	ova	larva	ova	larva	ova	larva
1	Zooplankton +Beroe	7	35.6±8			90	0	0	0	0	0
5	Zooplankton +Beroe	7	31.3±9.5			30	30	0	0	0	0
6	Zooplankton +Beroe	7	34.2±6			30	0	30		0	0
9	Zooplankton +Beroe	7	29.5±13			0	0	0	30	0	0
	Total Zooplanton + Beroe	**7**	**32.65±2.8**	**0**	**0**	**50**	**8**	**8**	**8**	**0**	**0**
2	Zooplankton + Mnemiopsis+ Beroe	7	37.7±8.5	263	38	120	0	0	90	60	0
10	Zooplankton + Mnemiopsis+ Beroe	7	39.1±7			180	0	0	0	0	0
	Total Zooplankton +Mnemiopsis +Beroe	**7**	**38.4±1**	**132**	**19**	**150**	**0**	**0**	**45**	**30**	**0**

Our estimations showed that *B. ovata* did not consume zooplankton and in conditions of absence *M.leidyi* just starved and decreased in size. (B.ovata+zooplankton) (Table 9).

Table 9 Numbers and size of *Beroe ovata* in experiments

No tank	Contents	Initial numbers of Beroe	Initial size mm	Final numbers of Beroe	Final size mm	% mortality
1	Zooplankton +Beroe	7	35.6±8	7	33.8±8.5	0
2	Zooplankton + Mnemiopsis+Beroe	7	37.7±8.5	7 263 ovae 38 larvae	38.6±8.0	0
5	Zooplankton +Beroe	7	31.3±9.5	6	27.5±9.0	14.3
6	Zooplankton +Beroe	7	34.2±6	6	33.7±8.5	14.3
9	Zooplankton +Beroe	7	29.5±13	7	18.8±6.5	0
10	Zooplankton + Mnemiopsis+Beroe	7	39.1±7	6	39.5±7	14.3

M.leidyi grazing rate on zooplankton was very high and zooplankton abundance in experimental tanks decreased in 4-6 times every day of experiment (M.leidyi+ zooplankton).

When we included in this trophic web (M.leidyi+zooplankton) *B.ovata* individuals, zooplankton abundance increase in 2 times, grazing pressure of *M.leidyi* decreased in the same proportions (*B.ovata+M.leidyi*+zooplankton).

We conclude that *B.ovata* is a specialized carnivore, which consumes exclusively zooplanktivorous ctenophores, in the case under examination *Mnemiopsis leidyi* and cannot digest zooplankton, fish larvae or other groups of gelatinous animals found in the Black and Caspian Seas.

Special investigations were conducted to study digestive enzymes of *B. ovata* in the Black Sea. It was found that digestive enzymes of *B.ovata* and *M.leidyi* are greatly differ. B.ovata does not have chitinaza, which enable to digest carapaces of Crustacea, while *M.leidyi* does have this enzyme (Dudkin et al., 2001).

7. Assessment of the role of *B. ovata* after its introduction in the Caspian Sea

It is assumed that *Beroe ovata*, once introduced will successfully establish itself, but it will develop to a large population size only about two years later, as happened with both ctenophores *B.ovata* and *M.leidyi* in the Black Sea.

B.ovata should be released in the Southern Caspian, where salinity and temperature are highest and where the main area of *M. leidyi* occurance and where it is most abundant. *B. ovata* has a seasonal development which starts in the August and continues till late November (Shiganova et al., 2001b). So, during the first year after the *B.ovata* introduction , the *M. leidyi* population size will still be maximal, but as of the next year, effects should be spectacular and quick. *B. ovata* may halve the *M. leidyi* population in two weeks and almost completely depress it in about two months in the Southern and Middle Caspian. *B. ovata* could also penetrate north to areas where salinity is above 7 ‰. Whether specimens will adjust to lower salinities in the long run is not to be excluded but cannot be guaranteed. The year after the first bloom of *B.ovata*, only few *M. leidyi* will initially be found in the Southern Caspian but during early summer *M.leidyi* may reach a high abundance again and spread to the north. However, in summer (in the Black Sea in July or August or probably earlier in the Caspian Sea due to earlier time of *M.leidyi* reproduction. *B.ovata* will catch up again, and undo the *Mnemiopsis* bloom. In all probability, this oscillating predator-prey system will continue for a long time, until such time as better measures for combating both jellies can be developed. It should indeed be borne in mind that instead of one jelly, two jellies will henceforth be present in the Caspian, and that both are of no use to man. A true win-win situation could only be created if both jellies could be harvested by a "third party (like a fish) that would represent a valuable resource for man via fisheries.

The experiments and investigations (see above) in the North American areas and in the Black Sea indeed showed that Beroe ovata will not consume any food except *M. leidyi* in the Caspian Sea. In the case of absence available prey – *B.ovata*, *B.ovata* decreases and finally stops reproduction, adult animals eliminate and other part of population stay moveless somewhere near the bottom and begin to develop again only in the case of appearance of prey.

Once introduced successfully into the Caspian Sea, *B.ovata* is not likely to go away. However, there is a way to increase the probability of extinction, consisting of keeping the primary inoculum as small as possible, such that genetic variation is kept to a minimum. Under a selfing reproductive strategy, that means that relatively few genotypes will be formed, and inbreeding depression may occur after a number of years (and presuming no new introductions, either accidentally by ballast water, or intentionally, have since taken place). *A priori* very little is known about inbreeding depression in ctenophores, and it is possible that this effect is only slight – as suggested by the fact that the Black Sea and Caspian populations of *M. leidyi* which presumably resulted from the inoculation of small propagules- show no sign of it. Still, it might pay to try and keep genetic variation down, and therefore it is recommended not to introduce more than 500 specimens at a time in one place and probably to repeat measurements two or three times in a season, and resort to new introductions for two next years.

7.1. Positive impacts to be expected

Annual biomass and abundance of *M. leidyi* will decline. Duration of the *M. leidyi* impact will decrease to not more than two months (July-August) and the impacted area will decrease; probably *M. leidyi* will no longer reach the Northern Caspian, except in isolated individuals.

If the start *of B. ovata* development in the Caspian turns out to be sooner than in the Black Sea, its effect on *M. leidyi* may even be faster than here predicted.

The following key results could be expected from a successful *B.ovata* introduction:

-*B. ovata* will only feed on *M. leidyi*, because no other ctenophore species is present

-In the short term, the depletion of zooplankton, including meroplankton, ichthyoplankton and demersal plankton sufficiently decrease to allow a restoration of its density, biomass and species diversity, especially of copepods. One caveat is that, if some of the endemic copepodas, onychopods, mysids and cumaceans have meanwhile been driven to extinction by *M.leidyi*, it will recover in some degree.

-The chain of events will continue: because their zooplankton food is restored to exploitable levels, in two years one can expect improvements in small pelagic planktivorous species, first of all the short cycle fish such as anchovy and big-eye kilka stock. Caspian seal and piscovorous stugeuns, in their turn, will benefit from restored kilka stocks, and recover their previous food sources.

8. Risk assessment in the case of introduction of *Beroe ovata*.

8.1. *B.ovata* is not able to develop in the Caspian Sea

An unlikely eventuality, because the experiments described above convincingly showed that *Beroe ovata* can live in the Caspian Sea water, feed on *M.leidyi* with high ingestion rate, growth and reproduce.

8.2. *B.ovata* will shift prey and feed on edible zooplankton, fish eggs and larvae

Many past introductions involving vertebrates have turned out in disaster, because the predator turned to new prey, that were not intended, and thereby added to the already existing damage instead of relieving it. Could this also happen in the present case? The Russian, Ukrainian and Iranian experiments and sum of knowledge from North American regions, where *Beroe ovata* originated from, convincingly showed that that *B.ovata* is a specialized carnivore that consumes exclusively planktivorous ctenophores and cannot digest zooplankton, fish eggs and larvae, or even other gelatinous animals such as the medusa *Aurelia aurita*. In the Black Sea which, for the purpose of the present evaluation can be considered a real-scale natural experiment, it feeds only on the two species of ctenophore present, *Mnemiopsis leidyi* and *Pleurobrachia pileus*

8.3. *Beroe ovata* will spread to rivers and international waters

The Caspian is a closed brackish water body, from which there is no escape for *Beroe*, since it dies at salinities below 4 ppt, and barely survives at 7 ‰.

8.4. Diseases and parasites of *Beroe spp*

In spite of all apparent optimism, might not *Beroe* carry as yet unknown diseases and parasites, perhaps with man as a final host? In fact, it must be conceded that nothing is currently known about diseases of ctenophores. No viral, bacterial, fungal or protozoan agents specific to ctenophores have been identified (Harbison et al.,1977).

Some ciliates, hyperiid amphipods (Hyperiidae and Oxycephalidae) are obligate parasites on ctenophores during their juvenile stages, and members of these families have been found on *Beroe* spp in the open sea.

Table 10 lists amphipods and copepods collected from ctenophores (Harbison et al., 1978). Aside from *Hyperoche mediterranea*, which burrows into the mesogloea of ctenophores, oxycephalids are the most commonly encountered predators and parasites of ctenophores. The specificity of this group does not seem to be as high as that of other groups of hyperiid amphipods. However, none of these have complex parasite cycles; in fact, they appear more as commensals than as strict parasites. Man, as a terrestrial organism, has no history of contact with ctenophores either, and it is therefore à priori very unlikely that he could function as a terminal or intermediate host for infective parasitoses for which ctenophores would serve as a reservoir. It would seem warranted to continue monitoring parasites and diseases of introduced *B.ovata* in the Caspian, but they cannot at present be taken seriously as a potential threat, according to the best knowledge currently available.

Table 10.

Hyperiid ampipods and copepods associated with one *Beroe* sp. Length (mm) of amphipods and copepods in parenthesis. (from Harbison et al., 1978).

1 female (15,0) *Phronima atrantica*

1 *Oxycephalus clausi*

49 juv.(6,5-7,7) *Rhabdosoma whitei*.

13 juv.(3,7-4,7) *Rhabdosoma* sp.

2 female (12,3-16,3) *R. whitei*.

Rhabdosoma sp.

Finally, since hyperiid amphipods do not occur in estuarine regions, they could exert little control on the bulk of the *Beroe ovata* populations in the Black Sea.

8.4.1. Parasite and bacteria analyses *of B. ovata* and *M. leidyi* in the Black and Caspian seas.

Comprehensive parasites, microbial and virus observations were performed in native basin (Black Sea) by scientists of AzNIIRKH and CaspNIRKH at the Black Sea station Utrish in accordance to Russian and international rules.

Analyses of 75 individuals of *B.ovata* and 25 *M.leidyi* were performed by Lartzeva L.V.(CaspNIRKH) in 2002 (st. Utrish) and 30 individuals Beroe, which were brought to the biostation Turali (Caspian shore). Results of examinations showed complete absence of any parasites.

Results of microbiological analyses:

The Black Sea water was seeded by 1,16 x 10^3 – 4,19 x 10^4 coe /ml;

The Caspian Sea water was seeded by 1,66 – 6,0 x 10^3 coe/ ml ;

In the Black Sea water *B.ovata* was seeded by 1,57x 10^3- 3,42 x 10^4 coe /g;

In the Caspian sea water after 7 days keeping in aqurium *B.ovata* was seeded by 1,66 x 10^3 – 6,0 x 10^3 coe/g;

In the Caspian Sea *Mnemiopsis leidyi* was seeded by 4,42x10^3- 5,03 x10^3 coe/g.

These results demonstrated that seeding microbial fauna in the Black and Caspian Sea are at the standard levels.

In July and September 2002 scientists of AzNIIRKH also were conducted parasite observations of comb jellies *M. leidyi* and *B. ovata* to determine species composition and invasion level of their parasite and simbiotic animals.

1200 individuals of *M.leidyi* and 1000 individuals of *B.ovata* of three sized groups (I – 6-12 cm, II – 2-5 cm and III < 2 cm.) were examined.

The following microbial fauna both simbionts and parasites were found during examination of *M. leidyi* and *B. ovata:*

Ciliary infusoria genus *Hemiophrys* (fam. *Amphileptidae*) were unitary found at the outer body surface and inside gastrovascular carvinity in caught *M. leidyi* and *B. ovata* in the sea.

Infusoria genus *Tetrachymena* were unitary found at 16 % of Beroe, which were kept in aquariums.

Ciliary infusoria were found in the meridianal canals and inside body of *B. ovata* and *M. leidyi*. They were found in 90 % of individuals *B. B.ovata*: 8,0-9,6 ind at the field of vision of I size group, 19,2 ind.– II size group and 52,0 ind. – III size group of *B. ovata*.

Thus microbial fauna of Beroe in the Black Sea is very poor and harmless. Most of representatives of them inhabit also in the Caspian Sea.

Virus examinations were performed with 70 individuals of *B. ovata*. None of virus cytopatogenic viruses were found.

In accordance with international norms for obtaining final epizootic status of *B.ovata* population must be examine twice a year during two or in the case of any harmful finding four years (Council Directive 91/67/EEC as last amended by Direktive 98/45/EC, 1988; 1991).

In the case of positive decision of Beroe introduction, samples of Beroe should be taken from the individuals selected for introduction. Beroe, selected for introduction, should be kept first for quarantine to avoid undesirable virus infections and microbial fauna from the Black Sea.

CONCLUSION AND RECOMMENDATIONS FOR FOLLOW-UP ACTIONS TO CONTROL INVASIVE SPECIES TRAFFIC AMONG THE CASPIAN AND THE BLACK AND BALTIC SEAS AND REGIONAL COLLABORATIVE PROCESS FOCUSING ON ML CONTROL SHOULD BE CONSIDERED AND SUBMITTED TO THE COP-IV.

- **The results of investigations since the appearance of *M. leidyi* in the Caspian Sea and recent monitoring data showed that no stabilization of M. leidyi population is observed; in fact changes in the past were temporary.**
- **The negative impacts of the increased numbers of *M. leidyi* enhanced by the eutrophication such as the appearance of the first coastal bloom of cyanobacteria along the Iranian coast in the Southern Caspian Sea in 2005, the increased phytoplankton biomass, the records of new invasive species, structural and quantitative changes in zoo-phytoplankton communities and Caspian kilka stocks stresses the need to control *M.leidyi* population in the Caspian Sea**
- **Experiments with many replications during three years confirm successful propagation and growth of *B. ovata* larvae in the Caspian Sea water at salinity 10-13‰. Mesocosm experiments conducted in Iran in 2003 proofed that *B.ovata* can not consume**

zooplankton, fish eggs and larvae. It does not have enzymes to digest these organisms. Beroe ovata is specialize predator on zooplanktivorous ctenophores and in some environments - on salps.

- **Currently, the only feasible control of *M. leidyi* in the Caspian Sea is the introduction of *B. ovata*. In order to mitigate the *M.leidyi* impact the urgent authorization of such introduction from all Caspian littoral countries is highly recommended.**
- **It is again strongly recommended that the existing ML monitoring program of all Caspian littoral states should be continued, including nutrient, plankton and benthic dynamics measurements. Moreover, there is strong need to apply standard methodology to monitor, assess and forecast spatial and temporal changes in the Mnemiopsis population in the Caspian Sea**
- **To investigate ways to reduce the impact of *M.leidyi* on Caspian kilka fisheries**
- **It is stressed the need to develop and implement a common methodology for ballast water management in line with IMO guidelines in order to prevent future introduction of invasive species in the Caspian Sea**
- **It is recommended using the ICES Code of Practice on the introduction and transfer of marine organisms as reference guidelines for biological control measures to be applied**
- **The CASPECO and TCIS is recommended to facilitate training in Mnemiopsis monitoring if necessary**
- **The Caspian littoral states should continue the revision of national and regional legislations regarding the intentional introduction of species into the Caspian Sea**

- **It is strongly recommended to continue work with the IAA (Inter Agency Agreement) between the CASPECO, TCIS and IMO with regard to the assessment of the extent of aquatic species transfer through ballast water and sediments and means of controlling these transfers into and out of the Caspian Sea**

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