

EFFECTS OF THE INVASIVE CTENOPHORE SPECIES, *MNEMIOPSIS LEIDYI*, ON THE CASPIAN SEA

Zahra KHOSHNOOD *, Reza KHOSHNOOD ** and Mehdi GHOBEITIHASAB *

* Islamic Azad University, Department of Experimental Sciences, Dezful Branch, Dezful, Iran, Zkhoshnood@gmail.com, Ghobeiti@yahoo.com

** Islamic Azad University, Department of Experimental Sciences, Dezful Branch, Tehran, Iran, Rezakhoshnood@gmail.com

KEYWORDS: invasive species, Caspian Sea, *Mnemiopsis leidyi*.

ABSTRACT

Human interventions on the Earth's natural systems are evident even in remote regions of the Antarctic and rain forests deep within the Amazon. In addition to human-induced climate change and habitat destruction, an emerging anthropogenic threat to biodiversity is the drastic species re-distribution (the movement of species from one place to another due to human intervention) at a global scale.

This creates fertile conditions for biological invasions which in turn cause substantial economic and ecological losses. These human-mediated invasions, often referred to as "biological pollution", are a worldwide problem that is increasing in frequency and magnitude, causing significant damage to the environment, economy and human health. Bioinvasions have strong impact on biodiversity and ecosystem functioning and stability. They are ranked as the second most important threat to biodiversity (after habitat destruction) by the World Conservation Union.

The Ctenophore, *Mnemiopsis leidyi*, is one of the invasive species that naturally lives in the Atlantic coastal waters of North America and South America, but discovered in Azov, Black, Caspian, North, Baltic and Mediterranean (north-eastern part) seas in early 1980s.

It seems that the main factor of its redistribution was the ballast waters of ships. As an alien species, *Mnemiopsis leidyi* caused many alterations in the Caspian Sea ecosystems. The fact that it feeds on the eggs of native fish *Clopeonella* spp., has resulted in a significant decline of its population; *Clopeonella* spp. were the main source of industrial fishing in the Caspian Sea and also the main source of food for precious fish species, the sturgeons, and therefore, their decline has caused a huge economical loss for the area's inhabitants and a significant decline of sturgeon populations.

This species has caused massive ecosystem changes and substantial economic losses in the late 1980s-1990s, and it has been recognized as a problem of main ecological concern for the sustainable development of the region, together with the high level of anthropogenic pressures on the Caspian Sea ecosystems. Some special characteristics of this species, such as adaptation to a wide range of salinity and temperature, high capability of reproduction, hermaphroditism and dissogeny, have led to huge increases of its mass, especially in southern regions of the Caspian Sea, the coastal waters of Iran. In addition, it has become clear that this species does not have any natural predators in the Caspian Sea, and also that it can feed on any organisms smaller than itself in size. Owing to these facts, it is a huge ecological threat for the Caspian Sea ecosystems. The aim of the present paper is to review the biological and ecological impacts of this invasive species on the Caspian Sea ecosystems.

ZUSAMMENFASSUNG: Die Auswirkungen der invasiven Ctenophoren-Art *Mnemiopsis leidyi* im Kaspischen Meer.

Die menschlichen Eingriffe in die natürlichen Ökosysteme der Erde sind unübersehbar sogar auch in den isolierten Gegenden der Antarktis und den Dickichten der tropischen Regenwälder des Amazonas. Zusätzlich zu den vom Menschen bedingten Klimaveränderungen und der Zerstörung der Lebensräume stellt eine drastische Umverteilung der Arten auf globaler Ebene, d.h. eine ebenfalls durch den Menschen bedingte Wanderung und Ausbreitung der Arten aus einem Gebiet in ein anderes, eine zunehmende Bedrohung für die Biodiversität dar.

Diese Tatsache schafft günstige Bedingungen für biologische Invasionen, die ihrerseits erhebliche wirtschaftliche und ökologische Verluste zur Folge haben. Die vom Menschen verursachten Invasionen, die oft als "biologische Verschmutzung" bezeichnet werden, stellen ein weltweites Problem dar, das an Häufigkeit und Ausmaß zunimmt und wesentliche Gefahren für Umwelt, Wirtschaft und menschliche Gesundheit in sich birgt. Bioinvasionen haben eine starke Auswirkung auf die Biodiversität, auf die Funktionsfähigkeit und Stabilität der Ökosysteme und werden von der Weltnaturschutzunion IUCN nach der Habitatzerstörung als die zweitgrößte Gefahr für die Biodiversität angesehen.

Die Ctenophoren/Rippenquallen-Art *Mnemiopsis leidyi* ist eine der invasiven Arten, die ihre natürlichen Lebensräume in den nord- und südamerikanischen Küstengewässern des Atlantischen Ozeans haben, jedoch in den frühen 1980-er Jahren im Asowschen, Schwarzen und Kaspischen Meer, der Nord- und Ostsee sowie im nordöstlichen Teil des Mittelmeeres entdeckt wurden.

Der Hauptfaktor für ihre Neuverteilung scheint das Ballastwasser von Schiffen gewesen zu sein. Als fremde Art hat *Mnemiopsis leidyi* viele Veränderungen im Ökosystem des Kaspischen Meeres verursacht. Die Tatsache, dass sich die Art von Eiern der einheimischen Fische *Clopeonella* spp. ernährt, hat zu einem erheblichen Niedergang deren Populationen geführt. *Clopeonella* Arten waren die Hauptquelle für industrielles Fischen im Kaspischen Meer sowie auch die Hauptnahrungsquelle für wertvolle Arten wie Störe. Daher hat ihr Rückgang zu einem gewaltigen wirtschaftlichen Verlust für die einheimische Bevölkerung und einem signifikanten Niedergang der Stör-Populationen geführt.

Mnemiopsis leidyi hat in den späten 1980-er und 1990-er Jahren massive Ökosystemveränderungen und beachtliche wirtschaftliche Verluste verursacht und wurde als ein ökologisches Hauptproblem für die nachhaltige Entwicklung der Region erkannt, so wie auch der hohe anthropogene Druck auf das Ökosystem des Kaspischen Meeres. Einige spezifische Kennzeichen der Art, wie die Anpassung an eine weite Spanne des Salzgehaltes und der Temperatur, eine hohe Reproduktionsfähigkeit, Hermaphroditismus und Dissogenie, haben zu einer gewaltigen Entwicklung ihrer Biomasse geführt, besonders in den südlichen Gebieten des Kaspischen Meeres, den Küstengewässern des Iran. Zusätzlich wurde die Erkenntnis gewonnen, dass die Art im Kaspischen Meer keine natürlichen Feinde hat und dass sie sich von beliebigen Organismen ernähren kann, die kleiner sind als sie selbst. In Anbetracht dieser Tatsachen stellt sie eine gewaltige Gefahr für das Ökosystem des Kaspischen Meeres dar. Ziel der vorliegenden Arbeit ist es, die biologischen und ökologischen Auswirkungen dieser invasiven Rippenqualle auf das Ökosystem des Kaspischen Meeres zu überprüfen und zu bewerten.

REZUMAT: Efectele ctenoforei invazive, specia *Mnemiopsis leidyi* în Marea Caspică.

Intervențiile umane asupra sistemelor naturale ale Pământului sunt evidente chiar și în regiunile izolate ale Antarticii și în profunzimea pădurilor tropicale ale Amazonului. Pe lângă schimbările climatice și distrugerea habitatelor induse de om, o amenințare antropogenă iminentă asupra biodiversității este redistribuirea drastică a speciilor (migrația speciilor dintr-un loc în altul datorită intervențiilor umane) la scară globală. Acest fapt generează condiții propice pentru invaziile biologice care pot cauza pierderi ecologice și economice substanțiale. Aceste invazii mijlocite de oameni se referă adesea la „poluarea biologică” și sunt o problemă la scară globală. Această problemă crește de la o zi la alta în frecvență și magnitudine generând impact negativ semnificativ asupra mediului, economiei și sănătății umane. Bioinvaziile au impact puternic asupra biodiversității, funcțiilor și stabilității ecosistemelor. Sunt clasate de către Uniunea Internațională pentru Conservare ca fiind după degradarea habitatelor a doua categorie de importanță în ceea ce privește amenințarea asupra biodiversității. Specia *Mnemiopsis leidyi*, aparținând încrengăturii Ctenophora, este una dintre speciile invazive care populează în mod natural apele de coastă ale Atlanticului în America de Nord și de Sud dar a fost descoperită și în mările: Azov, Neagră, Caspică, Nordului, Baltică și Mediterană (partea de nord-est) la începutul anilor 1980. Se pare că principalul factor care a contribuit la răspândirea acestei specii au fost transporturile navale. Ca specie alohtonă, *Mnemiopsis leidyi* a cauzat multe modificări negative în ecosistemele Mării Caspice. Faptul că se hrănește cu ouăle speciei autohtone *Clopeonella* sp. a determinat un regres numeric semnificativ al populațiilor acesteia. *Clopeonella* a fost principala sursă a pescuitului industrial din Marea Caspică și de asemenea principala sursă trofică pentru specii valoroase de pești, precum sturionii. De aceea declinul lor a generat pierderi economice majore pentru locuitorii zonei și un declin considerabil al populațiilor de sturioni.

Această specie a cauzat schimbări masive ale ecosistemelor și pierderi economice substanțiale între anii 1980-1990 și a fost percepută ca o problemă prioritară de natură ecologică pentru dezvoltarea sustenabilă a regiunii împreună cu gradul mare al presiunilor antropice asupra ecosistemelor Mării Caspice. Caracteristicile speciei precum adaptarea la variațiile mari ale salinității și temperaturii, capacitatea sporită de reproducere, hermafroditismul și disogenia au dus la răspândirea în masă a speciei mai ales în regiunea sudică a Mării Caspice, în apele de coastă ale Iranului. De asemenea a devenit clar faptul că această specie nu are prădători naturali în Marea Caspică și se poate hrăni cu orice organism mai mic decât ea. Din această cauză, reprezintă o amenințare ecologică de proporții asupra ecosistemelor Mării Caspice. Scopul lucrării de față este evaluarea impactului ecologic și biologic al acestei specii invazive asupra ecosistemelor Mării Caspice.

INTRODUCTION

Human interventions on the Earth's natural systems are evident even in remote regions of the Antarctic and rain forests deep within the Amazon. In addition to human-induced climate change and habitat destruction, an emerging anthropogenic threat to biodiversity is the drastic species re-distribution (the movement of species from one place to another due to human intervention) at a global scale.

In the aquatic systems, non-indigenous species, are occurring at an alarming rate and are causing global concern (Mack et al., 2000; Occhipinti-Ambrogi and Savini, 2003; Reusser and Lee, 2008). Yet, the consequences or ecological impacts of non-indigenous species are not always well understood, especially regarding the plankton organisms (Parker et al., 1999).

Typically, it is only when the non-indigenous species are widespread that it will cause some sort of ecological or economic harms, and thus earn the name invasive. However, there are several complicated stages along the path to becoming a successful invader. Several life cycles (i.e. quantitative shifts at the individual level) and life history (i.e. quantitative fluctuations at the population level) adaptations enable the invasive species to pass between each of the invasion stages and overcome several ecological barriers (Boero et al., 2008).

Over the last decades some cases of invasions of gelatinous plankters (medusae and/or Ctenophores) have been documented (Greve, 1994; Shiganova et al., 2001 a; Shiganova et al., 2001b; Zhilyakova et al., 2004; Purcell, 2005; Xian et al., 2005; Kawahara et al., 2006; Link and Ford, 2006). The impact of gelatinous plankton predation on marine biota became too obvious to be neglected when *Mnemiopsis leidyi*, an Atlantic ctenophore, was brought in the Caspian Sea, presumably by the ballast waters of oil tankers, and developed huge populations. Its massive occurrence was held responsible for the collapse of industrial fishing in this basin, impairing fish recruitment via predation on fish larvae and on their food as like as the other affected areas such as the Azov, Black, North, Baltic and Mediterranean (north-eastern part) seas (Belyaev and Solov'eva, 1995; Avsar, 1997; Berdnikov et al., 1999; Brodeur et al., 2002).

The Caspian Sea is the biggest enclosed water located between Iran, Azerbaijan, Russia, Kazakhstan and Turkmenistan, with a maximum length of 1,024 km and a maximum width of the 566 km and with a mean depth of 184 m. The low biodiversity, low salinity and being enclosed with high input of pollutants, made this environment, an endangered area.

The aim of the present paper is to review the biological and ecological impacts of this invasive species on the Caspian Sea.

MATERIALS AND METHODS

The ctenophores were sampled in the ports, coastal and offshore areas of the Iranian coastal waters of the Caspian Sea between April 2012 and March 2013 (Fig. 1).

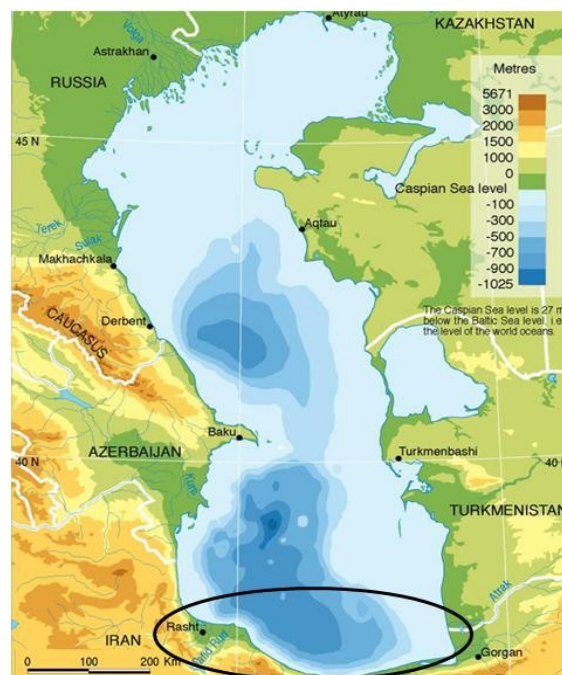


Figure 1: Sampling area; Iranian coastal waters of the Caspian Sea, showed by the circle.

Samples were collected by using the zooplankton net (1 m diameter, 500 μ m mesh size, fitted with a flow meter) and Nansen bottles.

Samples of the Ctenophores were immediately transferred to the laboratory after their collection and the observations were performed on living specimens.

Anatomical features of the Ctenophore samples were performed by using the light microscopy and stereomicroscopy.

RESULTS AND DISCUSSION

Morphological Features

Results of the microscopically studies of the *Mnemiopsis leidyi* showed that the ctenophore has a flattened ovoid body and the larger diameter of the ovoid is twice bigger than the smaller diameter. The body has two large lobes. The diameter of the specimens was 1.5-5 cm, and eight rows of cilia covered the body, these cilia rows were started at the ending part of the digestive system (anal part) to the oral portion of the body. Among these eight rows of cilia, four of them are longer and have more cilia and are located at the narrower parts of the body (Fig. 2).

Each row of the cilia has 240-450 cilia and at the end of them there were tentacles. The rows of cilia have bioluminescence. The digestive system is simple without any lateral canals and was composed of the mouth, pharynx and the stomach. The stomach contents of the specimens were mainly composed of zooplanktons (mainly *Acartia* sp. and *Calanodia* sp.), other species of copepods, larvae of the molluscs, larvae of the crustaceans, microbenthos and fish eggs. Results showed that 85% of the specimens have full or semi full stomach.



Figure 2: *Mnemiopsis leidyi* sampled from Caspian Sea.

Dispersion and abundance

Our results showed that in different depths (5, 10 and 20 m) of the Iranian coastal waters of Caspian Sea, the abundance of *Mnemiopsis leidyi* ranged between 425 g to 4,563 g. Data also showed that from the first occurrence of the *Mnemiopsis leidyi* in the Caspian Sea, in 2000 until the next couple of the years, the abundance of *Mnemiopsis leidyi* has increased.

Effects of *Mnemiopsis leidyi* on industrial fisheries

Ecological adaptations, food availability, higher water temperature and absence of major predators for the *Mnemiopsis leidyi* in the Caspian Sea ecosystem, were the most important reasons of the increases and dispersion of this invasive species in the southern parts of the Caspian Sea. Feeding on eggs and larvae of the *Clopeonella* spp. and being also in an intense feeding competition with these species were the most important reasons of significant decline in *Clopeonella* spp. community. Data records of the fish catching during 1989-1998 showed that the amounts of industrial fish catching (mainly *Clopeonella* spp.) increased from 7,902 t to 85,000 t, but after the increasing of the number of the *Mnemiopsis leidyi* in the next years, the industrial fish catching had a descending process until the complete shutdown of the industrial catching of the *Clopeonella* spp. Took place in 2001. The decline of the *Clopeonella* spp. population also has a negative effect on the population of the precious fish species, the sturgeons, because *Clopeonella* spp. was the main source of food for these species.

Effects of the *Mnemiopsis leidyi* on Caspian Sea

It is clear that *Mnemiopsis leidyi* has a significant effect on the zooplankton populations and the food webs. Its effects on the decline of the *Clopeonella* spp. and sturgeons was described previously, but the other ecological aspects that were affected by the invasion of the *Mnemiopsis leidyi* in the Caspian Sea were as follows:

- significant decline in planktonic population especially the zooplankton;
- significant decline of the Caspian Sea seal population, *Phoca caspica*;
- changes in the food web;
- chemical changes of the environment due to the decomposition of the dead ctenophores;
- decreasing and changing of the biodiversity.

Fighting strategies against the *Mnemiopsis leidyi*

In general, removing the invasive species from the new environment can be performed by different fighting strategies or combination of the different methods. These methods divided into different categories, like physical or mechanical, chemical, genetic methods, physiological methods and biological methods. Every one of these methods has different benefits and limitations, for example, physical or mechanical methods practically are impossible for the huge size environments like the Caspian Sea. Also genetic and physiological methods need expended investigations and financial resources. It seems that the biological fighting has fewer limitations except for the risk of the fact that the introduced species for elimination of the invasive species may become the new invasive species itself. For using of a predator species for the elimination of the *Mnemiopsis leidyi* from the Caspian Sea environment, this species must have these properties:

- high capacity of adaptation to the Caspian Sea environment;
- high capacity of breeding;
- high capacity of feeding on the ctenophore;
- being not a competitor for the endemic species;
- as far as possible with economic value.

In recent years one of the ctenophores of the Beroidae family accidentally (probably by the water currents) has entered in the Black Sea. This species, *Beroe ovata* (Fig. 3), has a great appetite for the *Mnemiopsis leidyi* and its breeding capacity is higher than the *Mnemiopsis leidyi*. Investigations in the Black Sea showed that it has a significant effect on the decline of the *Mnemiopsis leidyi*'s population. Unfortunately, one of the limiting factors for using *Beroe ovata* as the predator of the *Mnemiopsis leidyi* in the Caspian Sea is the different salinity in different parts of the Caspian Sea (i.e. higher salinity in southern and eastern parts and lower salinities mainly in northern parts), because it is cleared that *Beroe ovata* was basically adapted to lower salinities of less than the 10 ppt, while the southern parts of the Caspian Sea has a salinity of 13-14 ppt. Up to now no presence of *Beroe ovata* is reported in the Caspian Sea.



Figure 3: *Beroe ovata*, natural predator of the *Mnemiopsis leidyi*.

CONCLUSIONS

Invasion of the ctenophore species in the Caspian Sea resulted in ecological and economical damages. This invasive ctenophore, *Mnemiopsis leidyi*, known as the main factor of significant decline of the economically and ecologically important fish species, *Clopeonella* spp., also caused significant alterations in the Caspian seafood webs. Previous experience of the invasion of this species in the Black Sea showed that lack of the attention to the monitoring of the environment and establishment of new organisms as a result of transportation between different sea environments could result in the destruction of some ecosystems.

ACKNOWLEDGEMENTS

The authors wish to special thank the local fisheries research organization for providing the data records, also to Mr. Afkhami and Mrs. Ehsanpour for their great help during the experimental processes.

REFERENCES

1. Avsar D., 1997 – Possible reasons for the abundance of Black Sea sprat (*Sprattus sprattus phalericus* Risso, 1826) in relation to anchovy (*Engraulis encrasicolus* L., 1758) and a lobate ctenophora (*Mnemiopsis leidyi* Agassiz, 1865), *Cercetări Marine*, 29-30, 275-285.
2. Belyaev V. I. and Solov'eva N. V., 1995 – Modelling of the Black Sea ecosystem components with the comb jelly *Mnemiopsis leidyi*, *Dopovidi Akademii Nauk Ukrainskoi*, 1, 85-87.
3. Berdnikov S. V., Selyutin V. V., Vasilchenko V. V. and Caddy J. F., 1999 – Trophodynamic model of the Black and Azov Sea pelagic ecosystem: consequences of the comb jelly, *Mnemiopsis leidyi*, invasion, *Fisheries Research*, 42(3), 261-289.
4. Boero F., Bouillon J., Gravili C., Miglietta M. P., Parsons T. and Piraino S., 2008 – Gelatinous plankton: irregularities rule world (sometimes), *Marine Ecology-Progress Series*, 356, 299-310.
5. Brodeur R. D., Sugisaki H. and Hunt G. L., 2002 – Increases in jellyfish biomass in the Bering Sea: implications for the ecosystem, *Marine Ecology - Progress Series*, 233, 89-103.
6. Greve W., 1994 – The 1989 German Bight invasion of *Muggiaea atlantica*, *Ices Journal of Marine Science*, 51, 355-358.
7. Kawahara M., Uye S., Ohtsu K. and Izumi H., 2006 – Unusual population explosion of the giant jellyfish *Nemopilema nomurai* (Scyphozoa: Rhizostomeae) in East Asian waters, *Marine Ecology-Progress Series*, 307, 161-173.
8. Link J. S. and Ford M. D., 2006 – Widespread and persistent increase of Ctenophora in the continental shelf ecosystem of NE USA, *Marine Ecology - Progress Series*, 320, 153-159.
9. Mack R. N., Simberloff D., Lonsdale W. M., Evans H., Clout M. and Bazzaz F. A., 2000 – Biotic invasions, *Ecological Applications*, 10, 689-710.
10. Occhipinti-Ambrogi A. and Savini D., 2003 – Biological invasions as a component of global change in stressed marine ecosystems, *Marine Pollution Bulletin*, 46, 542-551.
11. Parker I. M., Simberloff D., Lonsdale W. M., Goodell K., Wonham M., Kareiva P. M., Williamson M. H., Von Holle B., Moyle P. B., Byers J. E. and Goldwasser L., 1999 – Impact Toward a Framework for Understanding the Ecological Effects of Invaders, *Biological Invasions*, 1, 3-19.
12. Purcell J. E., Uye S. I. and Lo W. T., 2007 – Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review, *Marine Ecology - Progress Series*, 350, 153-174.
13. Reusser D. A. and Lee H., 2008 – Predictions for an invaded world: a strategy to predict the distribution of native and non-indigenous species, *ICES Journal of Marine Science*, 65, 742-745.
14. Shiganova T. A., Bulgakova Y. V., Volovik S. P., Mirzoyan Z. A. and Dudkin S. I., 2001a – The new invader *Beroë ovata* Mayer 1912 and its effect on the ecosystem in the northeastern Black Sea, *Hydrobiologia*, 451, 187-197.
15. Shiganova T. A., Mirzoyan Z. A., Studenikina E. A., Volovik S. P., Siokou-Frangou I., Zervoudaki S., Christou E. D., Skirta A. Y. and Dumont H. J., 2001b – Population development of the invader ctenophore *Mnemiopsis leidyi* in the Black Sea and other seas of the Mediterranean basin, *Marine Biology*, 139, 431-445.