Biodiversity and recent exotic invasions of the Caspian Sea

Igor Plotnikov, Nikolai Aladin, Jean-Francois Cretaux, Philip Micklin,
Yuri Chuikov and Alexey Smurov

Introduction

The Caspian Sea is the world's largest lake (area 374 000 km^2; volume 78 200 km^3), greatly exceeding Lake Superior by 4.5 times in area and Lake Baikal by 3.5 times in volume (ZENKEVICH 1963). Several factors relate to the lake's unique history, morphometry, age and array of habitats that promote high biodiversity (ALADIN et al. 2002). Here, we briefly review the history and characteristics of Caspian Sea that have caused and maintained the currently observed high biodiversity. We also discuss recent exotic invasions and other potential threats to this unique ecosystem.

Key words: salt lakes, Caspian Sea, exotic species, biodiversity

Factors affecting biodiversity

The Caspian Sea's ancient origins, multiple sources of species, large latitudinal extent, uneven distribution of inflows and nutrient inputs, and low to moderate salinity have all contributed to high biodiversity. This lake, one of the world's most ancient continental lakes, is the remnant of the ancient, mainly epicontinental, Parathethys Sea. Consequently, the age of this reservoir is estimated differently by different researchers. Some authors give a figure of 5 millions years and count the age from Balakhanian time, others consider it 15 million years old and count from Low-Sarmatian time, and some indicate an even older age of 25–35 million years (ZENKEVICH 1963). Even accepting a minimal age estimate of 5–6 million years provides more than adequate time for the evaluation of a unique and diverse fauna and flora (ZENKEVICH 1963, KARPEVICH 1975, ALADIN et al. 2002).

The Volga River in the north dominates freshwater inflows to the Caspian Sea, contributing around 80%, and creates marked longitudinal variation in salinity. Thus, within the boundaries of the Caspian Sea there are actually three parallel coexisting ecosystems: freshwater, brackish water (mesohaline) and hyperhaline. These variable salinity conditions facilitate high Caspian Sea biodiversity. Due to the full salinity spectrum, freshwater, brackishwater, euryhaline and hyperhaline hydrobionts can live within the lake, and the marine-like chemistry of Caspian Sea waters permits many marine organisms.

Vertical salinity stratification in the modern Caspian Sea is weakly expressed, though salinity values at the bottom differ substantially from those on the surface (KOSAREV & YABLONSKAYA 1994). The lack of significant vertical stratification facilitates vertical mixing, and as a result, a relatively high oxygen content is observed near the bottom. However, when the Caspian Sea level was much higher than present, strong vertical salinity stratification was observed with practically no oxygen near bottom (KOSAREV & YABLONSKAYA 1994, DUMONT 1998). Low or anoxic conditions probably caused the current low diversity of abyssal fauna and flora observed at depths of more than 100–150 m. If not for these periods of low dissolved oxygen during ancient Caspian Sea level increases, deep-water biodiversity would probably be comparable to that of Lake Baikal.

In addition to strong salinity variation, biodiversity is promoted by the great longitudinal extent (1200 km) of the Caspian Sea, which causes large north-south temperature gradients. In the Northern Caspian, up to half the water area is covered by ice in winter, while in the Southern Caspian the temperature does not fall below 8–9 °C even in the coldest months (ZENKEVICH 1963). This kind of spatial distribution of surface water temperature allows occurrence of both cold-water and warm-water hydrobionts. Further habitat diversity is provided by strong vertical temperature stratification. Below thermocline water temperatures remain low even in the hottest summer months. In deep sites cold-water thermostatic conditions are actually observed without any seasonal changes. Presence of cold deep waters in the Caspian Sea allows even Arctic organisms to occupy their upper horizons (ZENKEVICH 1963, KOSAREV & YABLONSKAYA 1994). Thus, cold, moderate and warm water habitats exist in the lake.

0368-0770/06/0029-1578 $ 1.00

Production characteristic of various Caspian areas also differ due to the large inputs of nutrients associated with the Volga and Ural rivers. The areas near these river deltas are characterised by increased productivity due to organic fertilisers brought by river inflow. Some regions along the Middle Caspian eastern coasts are highly productive as well due to local upwelling. Thus, strong productivity gradients are observed in the Caspian Sea, and as a result hydrobionts adapted to oligo-, meso- and eutrophic conditions find suitable habitats (KARPEVICH 1975).

Sources of current Caspian Sea flora and fauna

The present fauna and flora of the Caspian Sea originate from four main sources: (1) Caspian, (2) Arctic, (3) Atlantic and Mediterranean, and (4) fresh-water (DERJAVIN 1912, BERG 1928, ZENKEVICH 1963).

Biodiversity of the Caspian Sea is 2.5 times lower than that of the Black Sea, and 5 times lower than that of the Barents Sea (ZENKEVICH 1963). Probably the main reason for relatively low species diversity is salinity variability. For true fresh-water species salinity is too high, but for organisms of marine origin salinity is too low. Therefore, conditions in the modern Caspian Sea are favourable only for brackish-water species originating from both marine and continental water bodies (MORDUKHAI-BOLTOVSKOY 1979). However, in comparison to freshwater lakes, the diverse salinity conditions in the Caspian Sea serve to increase biodiversity rather than reduce it.

Fishes and Crustacea have the largest number of species among all the groups of the Caspian Sea fauna (two-thirds of all recent species). The species diversity of these groups is largely determined by their osmoregulatory capacities, which allow these organisms to live in a wide range of salinities, from fresh water to even more saline than ocean water (ZENKEVICH 1963). Domination by these two groups in the modern Caspian Sea is further evidence that marked salinity variation has occurred in the past, and only species with strong osmoregulatory capacities could survive and give rise to adaptive radiation and speciation. Thus, modern biodiversity of the Caspian Sea reflects the complicated story of Palaeocaspian transgressions and regressions followed by freshening and salinization.

In addition to the original Caspian species, invaders from the Arctic are present in the current fauna and flora. How and when all these organisms came to the Caspian Sea is not known exactly, but several hypotheses have been proposed. EKMAN (1916) and SARS (1927) and later Humboldt (cited by ZENKEVICH 1963) propose it was the result of a direct contact between the Caspian Sea and Arctic Ocean. Grimm and Kessler (cited by ZENKEVICH 1963) suggest that arctic immigrants came from the North to the Caspian Sea via fresh water streams. Guriyanova and Pirozhnikov (cited by ZENKEVICH 1963) suggested the Kara Sea was a source of immigrants. All of these hypotheses have largely been abandoned due to lack of corroborating evidence.

BERG (1928) suggested that "Rybnoe Ozero" ("Fish Lake") stretched from the Baltic Sea to Ladoga Lake, from Ladoga to Onega Lake, from Onega to Beloe Ozero (White Lake), and from Beloe to Sheksna River. Thus, connecting the Caspian Sea with both Arctic and Baltic waters. Some modern scientists call this hypothetical lake "Mologa-Sheksna Lake" (ZENKEVICH 1963). They believe the so-called Arctic immigrants came neither from the Arctic Ocean directly nor from the Kara Sea, but from the Baltic and the White seas. All invaders from the Arctic show little or no sign of speciation, evidence of recent invasion or genetic conservatism.

Invasions of freshwater organisms into the Caspian Sea took place several times during periods when its salinity was lowest. The most ancient invaders among freshwater species are considered to be gastropods. The main ion composition, which differed essentially from that in the ocean (richer in calcium than ocean waters), facilitated this process to a large degree.

Atlantic and Mediterranean marine immigrants came to the Caspian Sea three times. The earliest immigrants came during Hvalynian time as early as 50 thousand years B.P. via the Kuma-Manychenskiy strait between the Black and Caspian seas (ZENKEVICH 1963). The next wave of immigrants came at the beginning of

the 20th century or a little later, some natural and others of anthropogenic origin. The last immigrants came during the mid-20th century with the opening of the Volga-Don canal in 1954 (KARPEVICH 1975). These invasions were mainly the result of ballast water dumping or organisms attaching to vessel hulls (KARPEVICH 1975). Deliberate acclimatization of aquatic species for food and industrial purposes also substantially affected the biodiversity of the Caspian Sea.

The full biodiversity of the Caspian Sea is still poorly known, and we expect many new species and subspecies to be described. Many true marine animals such as Scyphozoa, Anthozoa, Gordiacea, Gastrotricha, Kinorhyncha, Sipunculida, Phoronidea, Loricata, Scaphopoda, Tanaidacea, Pantopoda, Tardigrada, Asteroidea, Ophiuroidea, Echinoidea, Holothurioidea, Chaetognatha, Ascidiacea, Appendicularia and Acrania are not known in the Caspian Sea. Some of these organisms are capable osmoregulators, and being mostly euryhaline, thought capable of invading and surviving in the Caspian Sea. Many freshwater and brackish water species are living in the estuaries of rivers flowing into the Caspian Sea. If we include these species and expected, but yet undiscovered or reported, species, the diversity of the Caspian Sea will surpass that of Lake Baikal. ZENKEVITCH (1963) mentioned some 450 species of free-living Caspian Metazoa, CHESUNOV (1978) pointed out some 550 species, and KASYMOV (1987) recorded some 950 species. We may imagine that the real number of free-living Metazoa is some 1500–2000 species (ALADIN et al. 2002). Speciation in the Caspian Sea has resulted in overall high levels of endemism (about 42–46%), which is only slightly lower than that of Lake Baikal (about 54%). There is a high probability that after further studies in the Caspian Sea, the number of endemic species described could increase and reach that of Lake Baikal. Only the appearance of deep-water anoxic conditions in the ancient Caspian Sea during transgression is likely to have reduced the number of Caspian endemics. In some faunal groups of the Caspian that underwent adaptive radiations, the levels of endemism are close to 100%.

Current exotic invasions and other threats to biodiversity

Species from the Atlantic-Mediterranean are likely currently invading the Caspian Sea. A Ctenophore (*Mnemiopsis leidyi*) that just invaded the Caspian Sea (IVANOV et al. 2000, KAMAKIN 2005) could lead to an ecological catastrophe in this lake. This species impacted the fishery industry in the Black Sea, basically reducing stocks of fishes that prey on zooplankton. Researchers from Azerbaijan and Turkmenistan have already noted another Ctenophora (*Beroe ovata*) found in the Caspian Sea, although these are yet to be confirmed by photos, figures or collections. In addition to ctenophores, the medusa (*Aurelia aurita*) was recently found in the Caspian. At present, it is not certain whether *Beroe ovata* and *Aurelia aurita* are naturalized in the Caspian Sea. However, a population explosion of *Mnemiopsis leidyi* in the Southern Caspian reached 3951 ind./m^3 (KAMAKIN 2005). Not only the fishing industry but the whole ecosystem of the Caspian Sea could be endangered by this *Mnemiopsis* invasion (ALADIN et al. 2002, SHIGANOVA et al. 2003, KAMAKIN 2005).

Recently two additional species of Black Sea origin invaded the epilimnion of the Caspian Sea, the planktonic copepods *Acartia clausi* and *A. tonsa*. Last year, one more Cladocera (*Moina mongolica*) appeared in the central water zone of Northern and Middle Caspian Sea, although it is not known whether it will naturalize (ALADIN et al. 2003). Invaders from the Atlantic and Mediterranean will obviously continue to appear in the Caspian Sea until a new balance between aborigines and invaders is achieved. The time this balance will be reached is difficult to predict because at present the environment in the Caspian Sea is unstable due to changes in climate, anthropogenic pollution, and other environmental impacts. Changing abiotic and biotic components of the Caspian Sea will increase the risk of invasive species.

In addition to the threats posed by exotic invasions, the Caspian Sea faces an array of other threats to its biodiversity and health. These include pollution from oil and gas exploration and extraction both on the sea and along its coast; the transmission of these fuels by

pipelines under and near the sea; agricultural and industrial activities near the sea and its influent rivers that contribute pollution; overfishing and poaching (ZONN 1999); lake-level fluctuations; and global climate change. Multinational agreements containing strong and scientifically-based management actions will be required to preserve its biodiversity.

References

ALADIN, N.V., PLOTNIKOV, I.S.& FILIPPOV, A.A., 2002: Invaders in the Caspian Sea. – In: LEPPÄKOSKI, E., GOLLASCH, S. & OLENIN, S. (eds.): Invasive aquatic species of Europe. Distribution, impacts and management: 351–359. Kluwer Academic Publ.

ALADIN, N.V., PLOTNIKOV, I.S. & CHUIKOV, Y.S., 2003: Impact of introduced species on the ecosystem of the Caspian Sea. – In: Editors: Astrakhansky vestnik ekologicheskogo obrazovaniya,. **1**(5): 24–30 (in Russian).

BERG, L.S., 1928: About origin of northern elements in the Caspian fauna. – Proc. Acad. Sci. USSR **14**(3) (in Russian).

CHESUNOV, A.V., 1978: New species of free-living nematodes from the Caspian Sea. – Zool. Zh. **57**: 505–511 (in Russian).

DERJAVIN, A.N., 1912: Caspian elements in the Volga basin fauna. – Proc. Ichthyol. Lab. of Volga-Caspian Fishery and Seal-hunting 2, 5 (in Russian).

DUMONT, H.J., 1998: The Caspian Lake: History, biota, structure, and function. – Limnol. Oceanogr. **43**: 44–52.

EKMAN, S., 1916: Systematische und tiergeographische Bemerkungen über einige glacialmarine Relikte des Kaspischem Meeres. – Zool. Anz. **47**.

IVANOV, V.P., KAMAKIN, A.M., USHINTZEV, V.B., SHIGANOVA, T., ZHUKOVA, O., ALADIN, N., WILSON, S.I., HARBISON, G.R. & DUMONT, H.J., 2000: Invasion of the Caspian Sea by the comb jellyfish *Mnemiopsis leidyi* (Ctenophora). – Biol. Invasions **2**: 255–258.

KAMAKIN, A.M., 2005: Features of invader *Mnemiopsis leidyi* (A. Agassiz) (Ctenophora: Lobata) population forming in the Caspian Sea. – PhD diss., Astrakhan (in Russian).

KARPEVICH, A.F., 1975: Theory and practice of aquatic organisms acclimatisation. – Pischevaya promyshlennost, Moscow, 432 pp. (in Russian).

KASYMOV, A.G., 1987: The animal kingdom of the Caspian. – Elm Publishers, Baku, xxx pp. (in Russian).

KOSAREV, A.N. & YABLONSKAYA, E.A., 1994: The Caspian Sea. – SPB, The Hague, 259 pp.

MORDUKHAI-BOLTOVSKOY, P.D., 1979: Composition and distribution of Caspian Fauna in light of modern Data. – Int. Rev. Gesamt. Hydrobiol. **64**: 1–38.

SARS, G.O., 1927: Notes on the Crustacean fauna of the Caspian Sea. – In: editor: A Tribute to Prof. N. M. Knipovich. xx-xx. VNIRO, Moscow (in Russian).

SHIGANOVA, T.A., SAPOZHNIKOV, V.V., et al., 2003: Factors determining the conditions of distribution and quantitative characteristics of the ctenophore *Mnemiopsis leidyi* in the North Caspian. – Oceanology **43**: 676–693.

ZENKEVICH, L.A., 1963: Biology of the seas of the USSR. – Izd. AN SSSR, Moscow, 739 pp. (in Russian).

ZONN, I.S., 1999: Caspian: Illusions and Reality. – EDEL Editorial House, Moscow, 468 pp. (in Russian).

Authors' address:
Russian Academy of Sciences, Universitetskaya nab. 1, St. Petersburg 199034, Russia. E-mail: aral@zin.ru