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Article

Depth-related mollusk abundance distribution in the northern Caspian Sea

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Abstract. The abundance of mollusk species has been studied in the northern Caspian Sea in 2013–2017. MacArthur's broken stick species-abundance model was applied. The mollusk abundance varied in regard to the sea depth. At the depth range of 4–18 m, the mollusk community population structure was the most even. At 0–4-m depth range and at the depths exceeding 18 m, the mollusks were distributed more randomly. Such low evenness indicated the competition for resources, which was due to the low organic matter content in the bottom sediments. High mollusk abundance at 4–8-m depth range favors the feeding of benthophagous fish.

Keywords: Mollusca, bioindication, population density, MacArthur's broken stick species-abundance model, abundance

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Научная статья

Распределение видового обилия моллюсков Северного Каспия по глубинам

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Аннотация. Оценка видового обилия моллюсков Северного Каспия методом «разломанного стержня» Мак-Артура, проведенная в 2013–2017 гг., показала, что характер дифференциации сообщества изменяется на различных глубинах. Кривая распределения обилия видов в сообществе демонстрирует высокую выравненность в интервале изобат 4–18 м. Низкая выравненность обилия видов зарегистрирована в области, расположенной до 4-метровой изобаты, а также глубже 18 м. Нарушение выравненности обилия видов, свидетельствующее о наличии соревнования видов за ресурсы, обусловлено низким содержанием органического вещества в донных отложениях. Высокая суммарная плотность видов, зарегистрированная на глубинах 4–8 м, определяет благоприятные условия для нагула рыб-бентофагов.

Ключевые слова: Mollusca, биоиндикация, плотность видов, модель «разломанного стержня» Мак-Артура, обилие видов

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Introduction

The status of marine ecosystems is assessed both by measuring the pollution in the water and bottom sediment and by studying the response(s) of aquatic animals and plants to the changes in their habitat(s). Bioindication is a way to determine biologically significant loads; this method is based on analysis of the responses of living organisms and/or their communities; it is applicable to assess any type of anthropogenic pollution (Ermolaeva, 2022; Lyashenko, 2012). Using bioindication for zoobenthos is quite promising, since this ecological group is usually presented by sedentary organisms, which have long lifespan, so they can reflect the changes in the environmental conditions over a significant period (Shitikov et al., 2003).

Although the ecosystems of the northern Caspian Sea are faced recently with increasing concentrations of oil hydrocarbons, heavy metals, phenols, and pesticides, exceeding the allowable limits (Gurbanpur, 2010; Karygina, 2019; Karygina et al., 2020; Ostrovskaya and Umrikha, 2019; Zagriazniaiushchie veshchestva..., 2017), the number of bioindication studies in this area is extremely scarce.

Mollusks dominate in zoobenthos communities in the northern Caspian Sea (Kaspiiskoe..., 1985). Mollusk species are characterized by high abundance, they live in wide range of depths, water salinity, and dissolved oxygen content (Degtyareva et al., 2020; Kashin et al., 2022). Mollusks are food for benthophagous fish (Yablonskaya, 1975), so monitoring of their abundance allows to assess trophic conditions for ichthyofauna.

The study aims to assess the mollusk species abundance in the northern Caspian Sea using MacArthur's broken stick species-abundance model.

Materials and methods

The analyzed dataset comprised both published and original data collected during ongoing long-term studies aimed at assessing the mollusk communities of the northern Caspian Sea in regard to the depth, salinity, and oxygen content in the near-bottom water layer (Degtyareva et al., 2020; Kashin et al., 2022). In total, 246 samples were collected in the western part of the northern Caspian Sea at 48–50 stations in 2013–2017. The samples were processed according to generally accepted methods (Atlas..., 1968; Metodika..., 1975; Romanova, 1983). Samples were collected using a Petersen bottom grab ("Okean-50") with 0.1-m^2 capture area and 5.0-dm^3 volume. The samples were washed through a nylon sieve (mesh size 500 μm). The sampling period of 5 years without gaps allowed us to receive statistically solid dataset.

MacArthur's broken stick species-abundance model has a certain structure: X-axis represents the species rank, when the species are arranged from the most to the least abundant; Y-axis represents the number of specimens (Geografiya..., 2002; MacArthur, 1960; Shitikov and Rosenberg, 2005). MacArthur's broken stick species-abundance model takes into account the stock of a uniformly distributed resource available to the biological community. However, mollusk distribution is preconditioned by their habitat (Levich, 1996), including patchy distribution of the bottom sediment types and oxygen content. We consider the most applicable modification of this model by V.D. Fedorov, which takes into account the exponentially distributed resource (Fedorov, 1979). In this modification, the Y-axis represents the species abundance, i.e. the number of individuals per unit area.

The graphical method of presenting the results of the analysis of species abundance is the most effective (Geografiya..., 2002). In this case, the decimal logarithm of the species density is located on the Y-axis.

Results and discussion

In 2013–2017, mollusk abundance varied from 10 to 8,290 ind./m^2, biomass, from 0.003 to 1162.066 g/m^2. The frequency of occurrence was 64%. Mollusks were found down to the maximum depth in the northern Caspian Sea (29 m).

At the depth range of 0–3 m, five mollusk species have been found: *Abra segmentum* (Récluz, 1843), *Monodacna colorata* (Eichwald, 1829), *Cerastoderma glaucum* (Bruguière, 1789), *Adacna vitrea* (Eichwald, 1829), and *Didacna protracta* (Eichwald, 1829). Ranks 1, 2, and 3 were assigned to the three species with the highest (lg = 8.07) density: *A. segmentum*, *M. colorata*, and *C. glaucum.* The least abundant species, *D. protracta* (lg = 7.16), was assigned by rank 5 (Table 1).

At the 0–3-m depth range, the distribution of mollusk abundance was extremely uneven (Fig. 1). The niches of species assigned by ranks 1–3 overlapped, indicating a complex differentiation of the zoobenthic community in this area and evidence of species competition for resources. Since quantitative indicators of *A. segmentum*, *M. colorata*, and *D. protracta* here depended on the organic matter content in bottom sediments (Degtyareva, 2017), and the particles of bottom sediments were found in the gut of *C. glaucum* and *A. vitrea* (Yablonskaya, 1976), they may be considered as organic matter.

At the depth range of 3–4 m, five species were present. *D. protracta* was replaced here by *Mytilaster lineatus* (Gmelin, 1791). The distribution curve of the species abundance in the benthic community also had low evenness (Fig. 1). In general, the lowest density of mollusks was observed down to the 4-m isobath.

Below 4-m isobath, both the number of species in the benthic community (Table 1) and the maximum density of the first rank mollusk species (Fig. 2) increased. At the depth range of 4–8 m, new species were recorded: *Didacna barbotdemarnyi* (Grimm, 1877), *D. trigonoides* (Pallas, 1771), *Adacna laeviuscula* (Eichwald, 1829), and *Dreissena rostriformis* (Deshayes, 1838). In this part of the northern Caspian Sea, the river waters are totally dissolved in the sea waters, so the water salinity at this depth range exceeds 2‰ (Degtyareva et al., 2020). Here, flocculation processes take place (Lisitsyn, 1994), this brings favorable conditions for bivalves feeding on suspended matter (Bogutskaya et al., 2013). The maximum number of species is recorded in this zone. The community is even in regard to the species abundance, which indicates the absence of competition for the resources.

At the 8–13-m depth range, the benthic community was replenished with *Monodacna semipellucida* (Logvinenko and Starobogatov, 1967). In this area, the maximum evenness of the community in terms of species abundance was observed, since intensive accumulation of organic matter in bottom sediments was noted here (Karygina et al., 2013).

At the 13–18-m depth range, high evenness of species abundance (Fig. 3) is preconditioned by the most stable salt regime in this part of the water area (Degtyareva et al., 2020), favorable for the development of mollusk communities (Yablonskaya, 1975). *Theodoxus pallas* Lindholm, 1924 appeared in the zoobenthos.

Didacna parallela (Bogachev, 1932) and *Didacna pyramidata* (Grimm, 1877) were registered at the depths exceeding 18 m; both species occupied the lowest positions in the species ranking (Table 1). Below 18-m isobath, the species niches in the mollusk community overlapped (Fig. 3). Therefore, the benthic community here was characterized by high interspecific competition (Geografiya..., 2002). As water salinity exceeded 12‰, the content of organic matter in the bottom sediments decreased due to the diluting effect of the mineral component of the soils (Romankevich, 1977). Accordingly, this brought interspecific competition for food resources.

In general, the minimum species density was noted for *D. pyramidata* (lg = 7.23). Low species density (lg < 8) was observed for *D. parallella*, *T. pallasi*, *M. semipellucida*, and *D. rostriformis.* Species density of *D. trigonoides*, *A. laeviuscula*, *A. vitrea*, and *M. colorata* varied within lg = 8–9.

A higher density of species (lg > 9) was characteristic of *A. segmentum*, *D. barbotdemarnyi*, *C. glaucum*, and *D. protracta.* The maximum (lg = 9.80) was recorded in *M. lineatus.*

At the same time, the highest abundance of *M. colorata*, *A. segmentum*, *C. glaucum*, *A. vitrea*, and *D. barbotdemarnyi* was noted at the depth range of 4–8 m; for *D. protracta*, *M. lineatus*, *T. pallasi*, this was the depth range of 13–18 m; *M. semipellucida* dominated at the depth exceeding 18 m.

Table 1. Ranking of species at different depths in 2013–2017

Rank	Depth					
	< 3 m	3–4 m	4–8 m	8–13 m	13–18 m	> 18 m
1		*A. vitrea*	*A. segmentum*	*M. lineatus*	*M. lineatus*	*M. lineatus*
2	*M. colorata*, *A. segmentum*, *C. glaucum*	*A. segmentum*	*M. lineatus*	*D. protracta*	*D. protracta*	*C. glaucum*
3		*C. glaucum*	*D. protracta*	*C. glaucum*	*A. segmentum*	*D. protracta*
4	*A. vitrea*	*M. colorata*	*D. barbotdemarnyi*	*A. segmentum*	*C. glaucum*	*D. barbotdemarnyi*
5	*D. protracta*	*M. lineatus*	*C. glaucum*	*D. barbotdemarnyi*	*D. barbotdemarnyi*	*A. segmentum*
6	–	–	*M. colorata*	*M. colorata*	*A. vitrea*	*M. semipellucida*
7	–	–	*A. vitrea*	*A. vitrea*		*T. pallasi*
8	–	–	*A. laeviuscula*, *D. trigonoides*	*M. semipellucida*	*M. semipellucida*, *M. colorata*, *T. pallasi*	*D. parallella*
9	–	–		–		*D. pyramidata*
10	–	–	*D. rostriformis*	–	–	–

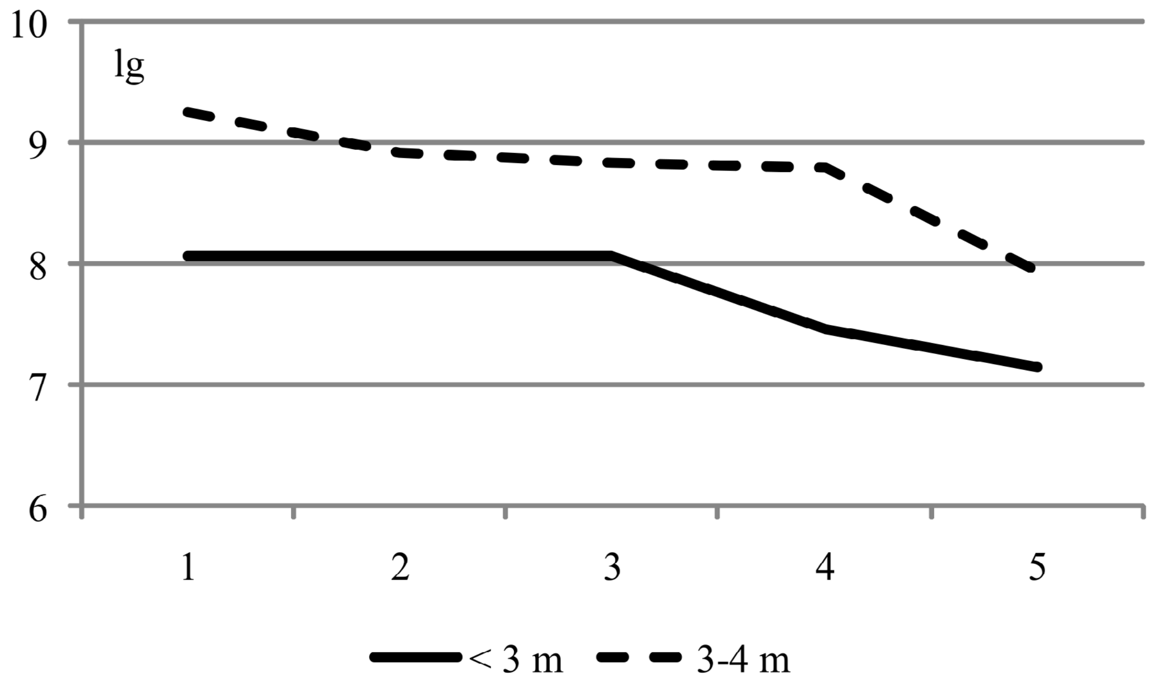

Fig. 1. MacArthur's broken stick species-abundance model at the depth range of 0–3 m and 3–4 m with rank/abundance (lg) axes.

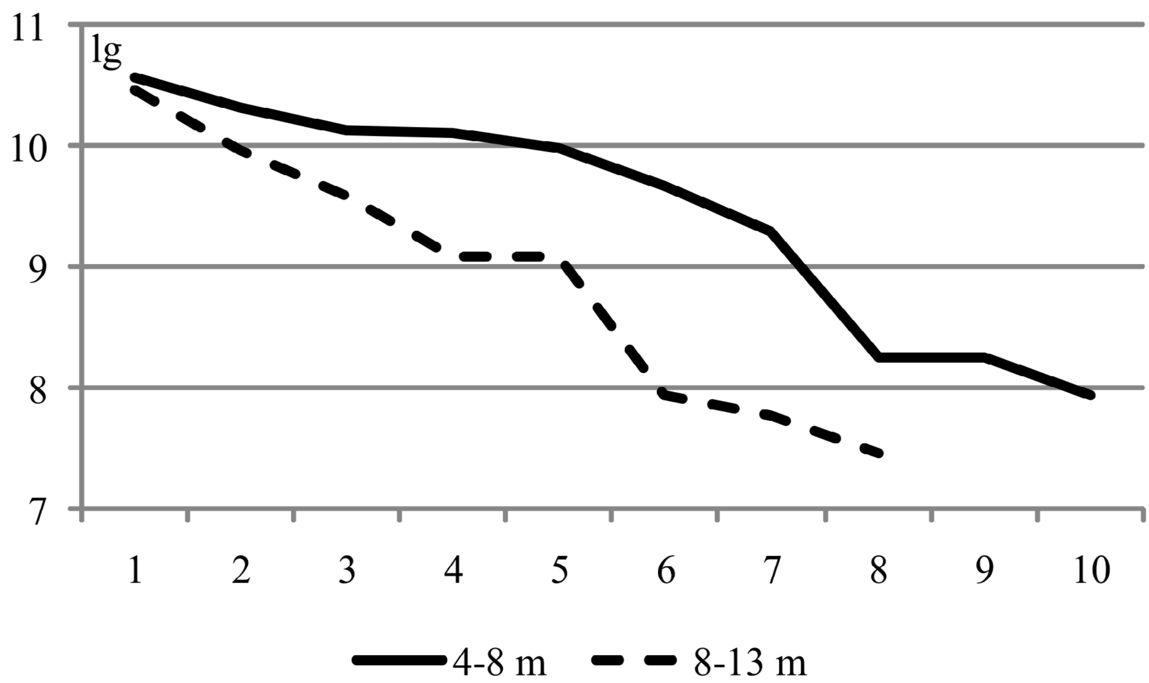

Fig. 2. MacArthur's broken stick species-abundance model in the depth ranges of 4–8 m and 8–13 m with rank/abundance (lg) axes.

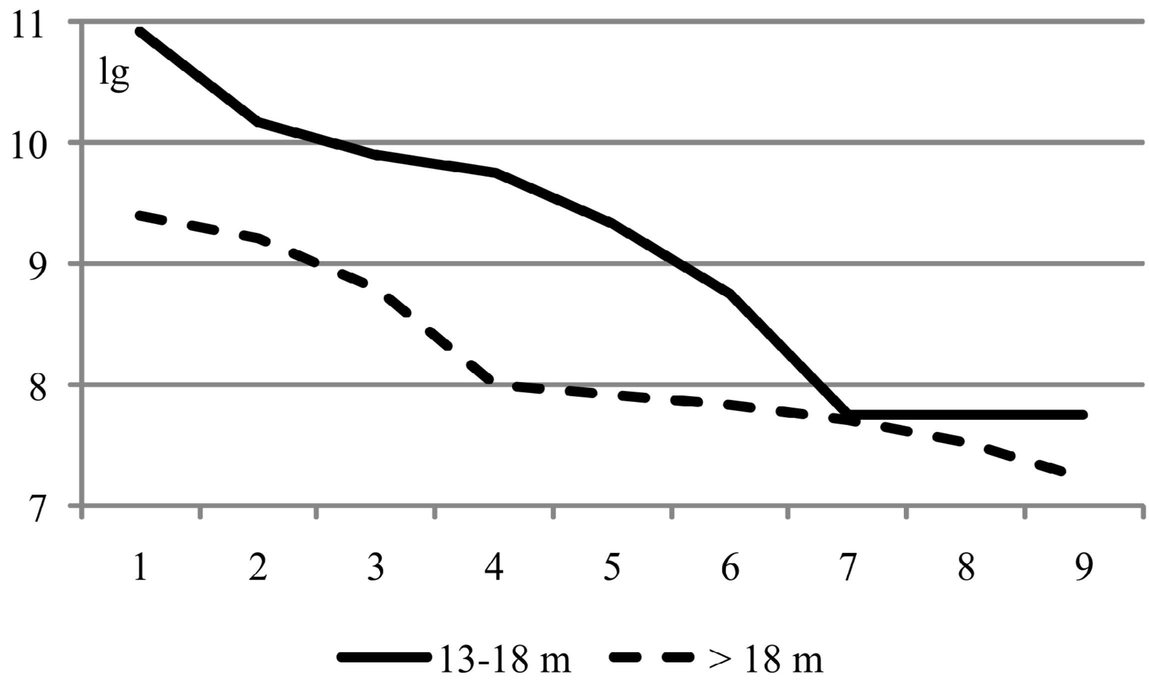

Fig. 3. MacArthur's broken stick species-abundance model in the depth range of 13–18 m and below 18-m isobath with rank/abundance (lg) axes.

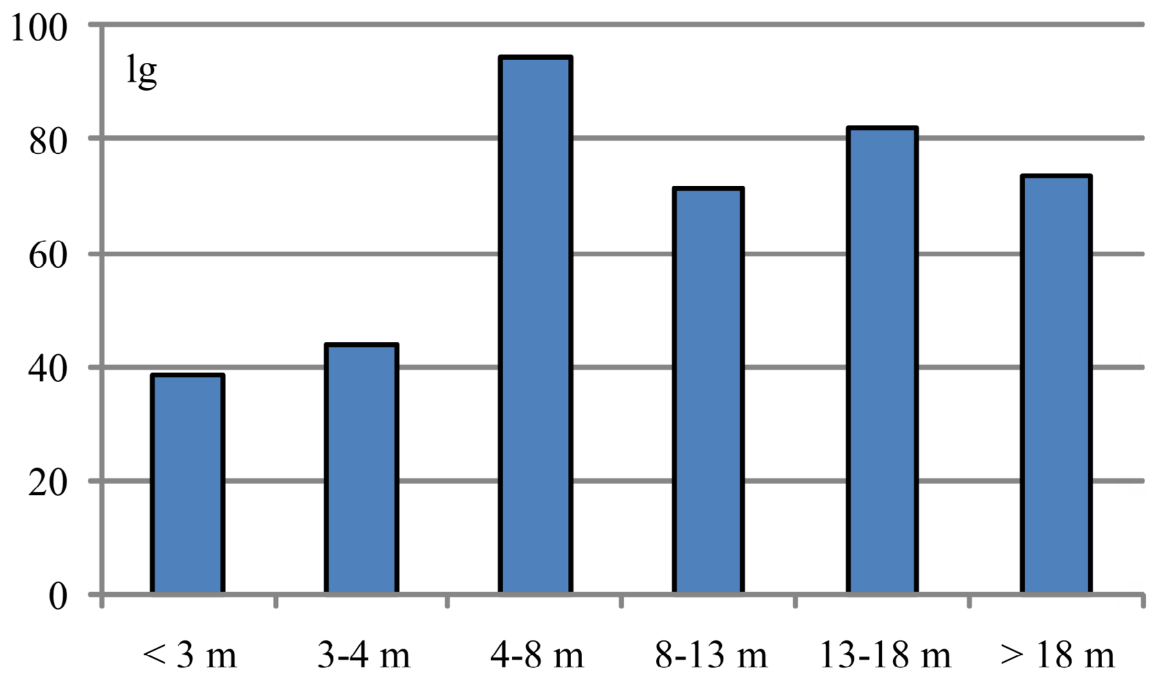

Fig. 4. Total population density of zoobenthos (lg) at different depths in 2013–2017.

The total mollusk abundance was low at the depth range of 0–4 m, increasing at deeper parts of the sea (Fig. 4). At the depth range of 4–8 m, the total population density was the highest. This area of the northern Caspian Sea is a feeding area for benthophagous fish: sturgeons (Acipenseridae), roach (*Rutilus rutilus caspicus* Yakovlev, 1870), and bream (*Abramis brama* Linnaeus, 1758). The most accumulations of stellate sturgeon (*Acipenser stellatus* Pallas, 1871) are registered in the Volga River delta (Safaraliev, 2018); of the Russian sturgeon (*Acipenser gueldenstaedtii* Brandt, 1833), at the 6–8-m depth range (Lepilina et al., 2013). Single specimens of sterlet (*Acipenser ruthenus* Linnaeus, 1758) were found in the Northern Caspian at the depth range of 3–7 m (Kalmykov, 2005). The largest accumulations of roach were recorded at depths of 4.0–7.5 m (Barabanov, 2020). Bream accumulations are formed in the areas where water salinity does not exceed 6‰ (Kravchenko, 2013). Therefore, the feeding area of mollusk-eating fish is characterized by a sufficient food supply.

Conclusions

Nowadays, the state of the ecosystems of the northern Caspian Sea has been deteriorating. Despite numerous studies of water and bottom sediment pollution in this area, there are very few studies devoted to the response of aquatic organisms to these environmental changes. Until recently, no assessment of the quality of the marine environment by bioindication methods has been carried out. The assessment of the mollusk species abundance in the northern Caspian Sea using the MacArthur's broken stick species-abundance model was carried out for the first time.

Our analysis showed uneven distribution of abundance of mollusk species at different depths. Low evenness of species abundance, indicating the interspecific competition, was registered for the depth range of 0–4 m and at the depths exceeding 18 m. Interspecific competition at these depths is formed due to the low level of accumulation of organic matter in bottom sediments.

The even distribution curve of the species abundance at the depths range of 4–18 m indicates the absence of competition between mollusk species here.

The high total population density recorded at depths of 4–8 m creates favourable conditions for feeding of benthophagous fish.

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