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Alien Species in the Ichthyofauna of Northwestern Part of the Azov Sea Basin

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Abstract—There are nine alien species in the region of the study. The distribution and abundance of nonnative fish in the reservoirs of northwestern part of the Azov Sea basin depends on the scale of fishing industry activities, the degree of transformation of hydroecosystems, and the water release into the rivers from irrigation canals. There are three groups of species registered according to the number indices in the water areas of the basin. The first is the species the findings of which are rare in the region; the second group comprises fish the number of which depends on fishing industry activities; and the third one embraces the species that are high in the number and their self-reproducing populations exist.

Keywords: alien species, northwestern part of the Azov Sea basin, so-iuy mullet, Prussian carp, pumpkinseed
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INTRODUCTION

The species composition of alien fish species in the Azov-Black Sea basin has been described by a number of authors (Alexandrov et al., 2007; *Vselentsy v bioraznoobrazii...*, 2010; Slynko et al., 2010). The Azov Sea basin is considered in these studies as a transit that does not make it possible today to determine the species composition of alien species directly for the sea and estuaries. So in the study (*Vselentsy v bioraznoobrazii...*, 2010), an attempt was made to estimate the species composition of invasive species in the Sea of Azov and to characterize selected fish species using the example of Taganrog Bay.

The northwestern part of the Azov Sea basin is a system of large estuaries, bays, and small rivers which act under the influence of significant transformations of both natural and anthropogenic character. Thus, regular Dnieper water releases from canals of the North Crimean and Kakhovskaya irrigation systems were noted for the Eastern Sivash, the Utlyuk estuary, the Maly and Bolshoy Utlyuk rivers, and the Molochnaya River. The Molochny estuary was the testing ground for naturalization of a Far Eastern so-iuy mullet. The intensive works on fish farming in the small rivers of the region led to immigration of many alien fish species (Movchan and Smirnov, 1983). The natural changes in salinity in the Sea of Azov promoted penetration into the reservoir of many Black Sea and Mediterranean fish species (Volovik and Chikhachev, 1998). Thus, the reservoirs of northwestern part of the Azov Sea basin are characterized by complex invasive processes that affect the structure of fish communities (Naseka and Diripasko, 2005; *Vselentsy v bioraznoobrazii...*, 2010). That was why we made an attempt to characterize the species composition and the most numerous alien fish species in the reservoirs of northwestern part of the Azov Sea basin according to the published data and our own research.

MATERIALS AND METHODS

The results of our research were used in the period of 1996–2012 in various areas of the sea and rivers to determine the species composition of alien fishes. There were 1635 catches by different fishing gear over the specified period. We used gillnets (18–110 mm mesh), fry fingering trawl (6.5 mm mesh), trap nets (6.5–18 mm mesh), seine (40 mm mesh), goby dredges (14–18 mm mesh), and stationary seine (16 mm mesh) to obtain the source material. The fishing was conducted both in a coastal zone and in the open sea. A considerable part of the material was collected from the stations in northwestern part of the sea near the mouth of the Molochny estuary and on the spit of Biriuchi Island. Also, fieldworks were carried out several times a year in various water areas of the sea and rivers in the region (Fig. 1).

The published data were used to clarify and supplement both the historical and modern fish species composition in the Azov Sea basin (Ostroumov, 1897;

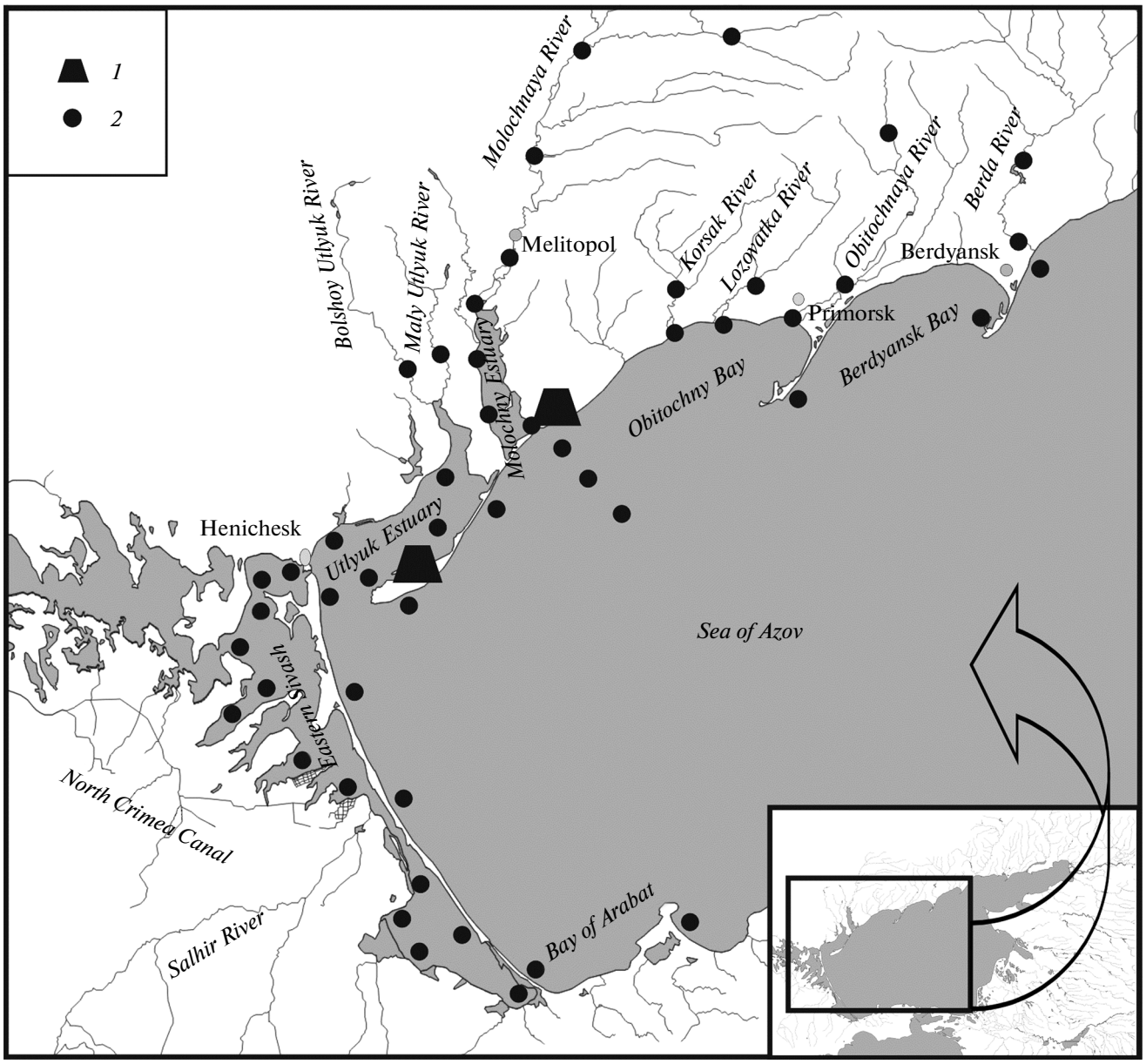

Fig. 1. Venues of the stationary (*1*) and field (*2*) investigations in the northwestern part of the Azov Sea basin.

Radionova, 1936; Slastenenko, 1938; Tarnavskii, 1960; Mel'nikov and Chaplina, 1961; Mel'nikov and Chaplina, 1962; Loshakov, 1963; Svetovidov, 1964; Yankovskii, 1965; Delyamure, 1966; Volovik and Dakhno, 1983; *Gidrometeorologiya*..., 1991; Volovik and Chikhachev, 1998; Diripasko et al., 2011; Luzhnyak et al., 2011).

RESULTS AND DISCUSSION

General overview of the fauna of alien fish species. There are nine alien species in general for the region. So-iuy mullet (*Liza haematocheilus*) and Prussian carp (*Carassius auratus gibelio*) are widespread, which formed self-reproducing populations and are actively used by the fishing industry. The species which were noted in the basin recently comprise Chinese medaka (*Oryzias sinensis*), stone moroko (*Pseudorasbora parva*), and pumpkinseed (*Lepomis gibbosus*). The last two spread most intensely in the reservoirs of the region. This is promoted, on one hand, by their eurybiontic property and, on the other hand, by human activities. So the construction of a number of interbasin canals in southern Ukraine has created conditions for expansion of the range of pumpkinseed and stone moroko, as these waterworks are used by them as an invasion corridor. The first findings of pumpkinseed in the studied region are confined to the water release

areas of the Kakhovskaya irrigation system in the Molochnaya (Diripasko et al., 2008) and Maly Utlyuk rivers. In addition, the infestation by pump kinseed and stone moroko in many fish rearing stations in southern Ukraine promotes their distribution in other reservoirs with the seeding. The centers of immigration of the stone moroko became the fishery waters in the reservoirs of the Molochnaya and Berda rivers, from where they got into the river system of the region. There are also the species in the reservoirs of the northwestern part of the Azov Sea basin whose distribution and number depend on the stocking volumes. Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), and black carp (*Mylopharyngodon piceus*) belong to them.

The alien species can be divided conditionally in number into several groups. The first group is rare species the findings of which are rare in the region and quite local. The Chinese medaka, which was noted in the Obitochnaya River, belongs to this group (Naseka and Diripasko, 2005). Considering the single findings of the species, it is difficult today to specify the reasons influencing its abundance. It should be noted that, over the last years, the special biotechnical measures oriented to immigration of medaka in the freshwater bodies of the northern Sea of Azov coastal region for the purpose of blood-sucking insect control were not carried out. However, some potential reasons for the appearance of medaka in the region of the study are given: namely, the unintentional delivery with fish stocking material in fish farming and use of the species as an item of the aquarium industry with accidental release into natural water bodies (Naseka and Diripasko, 2005).

To the second group, it is necessary to assign fish species whose number depends on the intensity of fishing industry activities. A characteristic of these species is the impossibility to create a self-reproducing population. Silver carp, bighead carp, grass carp, and black carp belong to this group, which are widely distributed in the Azov Sea basin. The majority of fish ponds are actively stocked with these species, and thus they escape into the rivers and offshore zones. The facts of catches of bighead and grass carp in the Sea of Azov far from the mouths of rivers are especially interesting.

According to our observations, they are registered singly, but regularly, in the coastal areas of the sea with salinity of 8–11‰.

The third group of species is the most dynamic in abundance and distribution. We assign pumpkinseed, Prussian carp, so-iuy mullet, and stone moroko to it. All of them formed self-reproducing populations in the region of the study, actively settled, and have rather high abundance, which is determined by a wide range of factors. The intensity of the fishing industry activities and the volume of water release into the rivers from canals of the irrigation systems can be distinguished as the main factors.

Characteristics of the most numerous alien fish species. As was described earlier, the most numerous alien species are Prussian carp, so-iuy mullet, and pumpkinseed. They are widespread in the region of the study and have a tendency to further range expansion. In addition, Prussian carp and so-iuy mullet have commercial importance in the Sea of Azov, which requires monitoring of the state of their population. Pumpkinseed, in turn, is the "youngest" invader in the Azov Sea basin and its intense expansion requires study and further forecasting.

Prussian carp. Prussian carp was imported to Ukraine for the first time into ponds in Vinnytsa oblast (Central Ukraine) at the beginning of the 20th century from water bodies in Poland (Bilii, 1933). In the next years, the species was intensely used as an object of aquaculture for stocking of ponds, from where it independently penetrated into the river systems. Therefore, since the 1950s, carp has become a common species for the majority of the rivers in Ukraine (Movchan and Smirnov, 1983). The same pattern was observed in the rivers of the Azov Sea basin, where it was not noted until the middle of the last century (Kurilo-Krimchak, 1932; Beling and Gimmel'reikh, 1940; Markevich and Korotkyi, 1954). However, the increase in the scales of pond culture in the 1960s came amid the introduction into the ponds of stocking material and fry of Prussian carp, which led to spontaneous naturalization of this species in the freshwater bodies of the whole Azov Sea basin (Ivanchenko and Balandina, 1987). The studies of the ichtyofauna in this region showed that the species formed from the late 1950s separate numerous populations in the majority of the rivers in the basin. So it was noted by many authors in the Salhir, Bolshoy and Maly Utlyuk, Molochnaya, Lozovatka, Obitochnaya, and Berda rivers (Mel'nikov and Chaplina, 1961, 1962; Loshakov, 1963; Delyamure, 1966).

The species was especially numerous in the lower reaches of the Molochnaya River and in the middle part of the Berda River (Loshakov, 1963). Considering such a number, one can assume that Prussian carp could escape into adjacent water bodies, but it is absent in the fauna of the Eastern Sivash and the Utlyuk and Molochny estuaries according to results of the icthyological investigations carried out in the early to middle part of the last century (Radionova, 1936; Tarnavskii, 1960; Pavlov, 1961; Yankovskii, 1965). Analyzing the lists of fish species directly in the Sea of Azov, one should note its lack in the ichthyofauna of the sea, about which numerous works indicate until the mid-1980s (Karpevich, 1955; Maiskii, 1955; Svetovidov, 1964; Volovik and Dakhno, 1983; Volovik and Chikhachev, 1998).

Beginning in 1986, the species was registered in the sea, and it was used precisely from that time in the Azov–Don and Azov–Kubansk regions as a commercial object (Ivanchenko and Luk'yanov, 2006). This

Alien fish species in the northwestern part of the Azov Sea basin

Species	Ecological group	Vector of invasion	Places of findings
Stone moroko—*Pseudorasbora parva*	Freshwater	Fish culture	Ponds in the basin of the Berda and Molochnaya rivers
Silver carp—*Hypophthalmichthys molitrix*	Freshwater	Fish culture	Ponds in the basin of small rivers, water areas of the Sea of Azov, and the Utlyuk estuary
Bighead carp—*Aristichthys nobilis*	Freshwater	Fish culture	Ponds in the basin of small rivers, water areas of the Sea of Azov, and the Utlyuk estuary
Grass carp—*Ctenopharyngodon idella*	Freshwater	Fish culture	Ponds in the basin of small rivers
Black carp—*Mylopharyngodon piceus*	Freshwater	Fish culture	Ponds in the basin of small rivers
Prussian carp—*Carassius auratus gibelio*	Freshwater	Fish culture	Basin of small rivers, water areas of the Sea of Azov, Eastern Sivash, the Utlyuk and Molochny estuaries
So-iuy mullet—*Liza haematocheilus*	Marine	Fish culture	Basin of small rivers, water areas of the Sea of Azov, Eastern Sivash, the Utlyuk and Molochny estuaries
Chinese medaka—*Oryzias sinensis*	Freshwater	Fish culture	Single finding in the Obitochnaya River
Pumpkinseed—*Lepomis gibbosus*	Freshwater	Water engineering	Single finding in the Utlyuk estuary of the Sea of Azov, the Maly Utlyuk, Molochnaya, and Berda rivers

species was discarded and released as a coarce fish by seining fish from the ponds. As a result of this in the high water period of 1979–1981, the Prussian carp found favorable conditions for reproduction in the floodplains of the Don and in the Kuban estuaries; its number sharply increased; it widely settled in the region. For feeding, the Prussian carp began to use the eastern part of Taganrog Bay to the isohaline of 3–4‰ and desalinated zone of the sea (Ivanchenko and Balandina, 1987).

The modern area of Prussian carp in northwestern part of the Azov Sea basin significantly expanded. This process was promoted by the marked trend toward a decrease in salinity of the marine waters on average to 9–10‰, which has occurred since 1998 (*Sreda, biota*..., 2001). In addition, separate water areas of the Eastern Sivash were desalinated to the level of 4–9‰ as a result of significant freshwater releases from canals of the North Crimean irrigation system (Demchenko, 2005). Such changes in the environmental conditions in the water bodies led to the widespread distribution of the species in the Sea of Azov and its estuaries and bays. Today the Prussian carp can be found along the coast of the Sea of Azov, in a branch of the Molochny estuary, in all water areas of the Utlyuk estuary, and in the desalinated areas of the Sivash (Demchenko, 2001, 2005; Diripasko et al., 2001; Mityai et al., 2001) (Fig. 2).

Analyzing the structure of catches in various water bodies of the Azov Sea basin, one should note that Prussian carp is found most often in the Utlyuk estuary—in every second catch (Fig. 3). Its high number in the estuary is connected to spawning migrations to the Bolshoy and Maly Utlyuk rivers (Fig. 2). This species is very rare in the Molochny estuary; the indices of its finding in catches are a little more than 6%. In most cases, the carp is found in a branch of the Molochny estuary and does not spread further in other areas of the water body in connection with the high indices of its water salinity.

In the Eastern Sivash, Prussian carp is noted in the desalinated areas, as well as in the Tonkoy canal from the Sea of Azov side. In the desalinated areas of the Sivash, more than 90% of the caught fishes were immature. This is related to the intense spawning of the Prussian carp and the high density of fry of this species in canals of the irrigation system. A considerable fraction of fingerlings are carried out by the current to the estuary water areas of the Sivash, where they live in the summer–autumn period.

According to the results of analysis of the structure of catches from different gear, in the coastal zone of the Sea of Azov, individuals of Prussian carp are found practically in every tenth catch. The carp is most often observed during the spring and summer catches and is

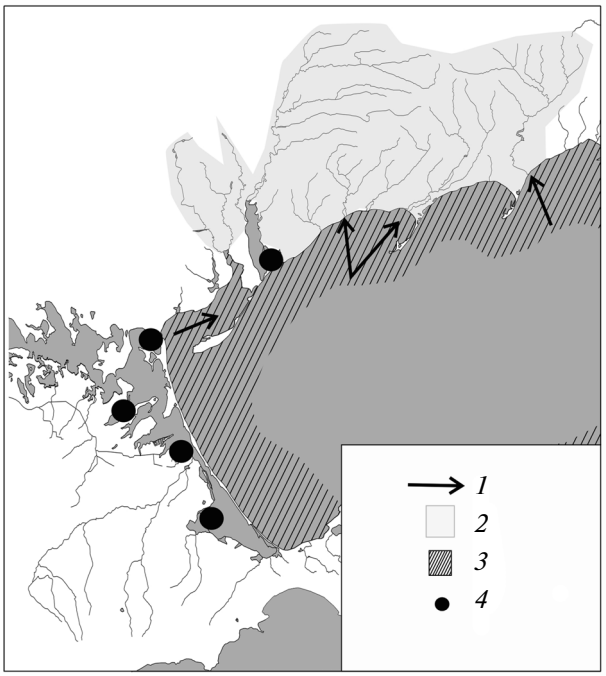

Fig. 2. Schematic map of distribution of Prussian carp in the reservoirs of the northwestern part of the Azov Sea basin: (*1*) spawning migrations; (*2*) regular places of findings in the river basins; (*3*) places of findings in the water areas of the Sea of Azov and the Utlyuk estuary; (*4*) irregular places of findings.

rarer during the autumn. Its course along the coast occurs in large aggregations. Thus, in 1998 during the spring fishing season in the Sea of Azov near the mouth of the Molochny estuary, 200 kg of individuals of this species were captured by a drag seine. In the next years, smaller catches were registered in different gear, although sometimes the Prussian carp dominated in the structure both in number and by weight.

In the rivers of the region of study, Prussian carp is found everywhere (Demchenko, 2009). Its highest abundance is observed in the Lozovatka, Korsak, Bolshoy and Maly Utlyuk rivers. The frequency of findings in the catches for these water bodies is on average about 70% (Fig. 3).

The long-term dynamics in the frequency of findings of Prussian carp in the catches of different fishing gear in the Sea of Azov shows an increase in its abundance, which is clearly related to lower water salinity (Fig. 4). In view of this, we will note that Prussian carp is a more euryhaline species than was considered earlier. Some authors believe that at present there is a process of formation of its semianadromous form in the Azov Sea basin (Boltachev and Danilyuk, 2006).

As shown above, in the current conditions, the abundance of the Prussian carp in the Sea of Azov is increasing. In 2001, this species began to be considered in the fishery (Fig. 5b). Such increase in number is related to the fishing activities in the river basins, the

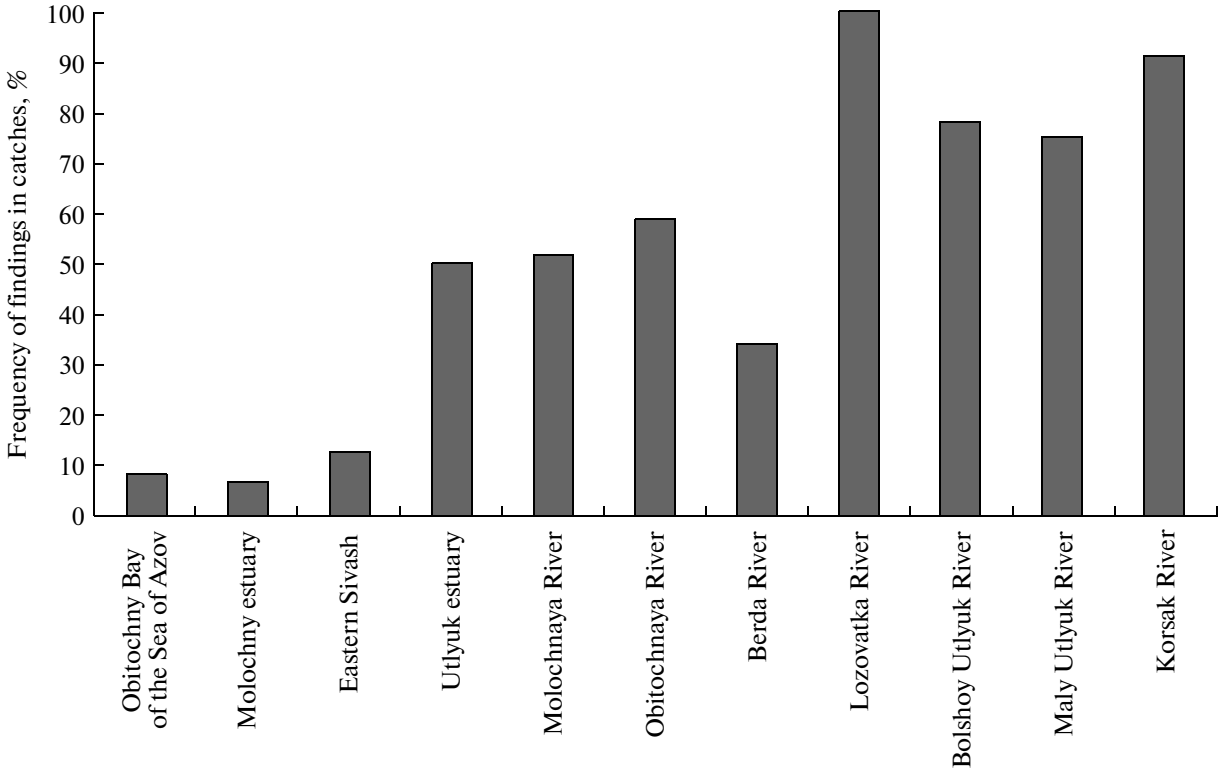

Fig. 3. Frequency of findings of Prussian carp in the catches in the water bodies of the Azov Sea basin.

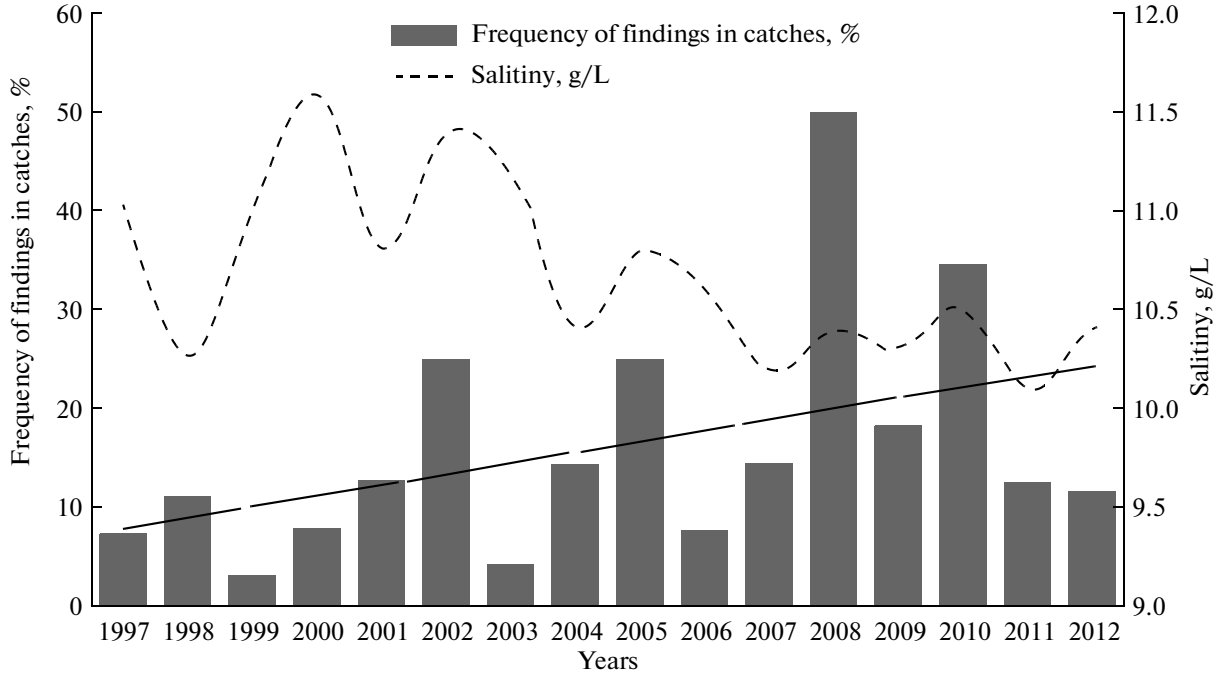

Fig. 4. Frequency of findings of Prussian carp in catches in the Sea of Azov under the conditions of decrease in salinity.

desalination of coastal water areas of the sea, and the decrease in predation pressure. A number of authors (Abramenko, 2011) attribute also changes in the genetic structure to the reasons for the increase in abundance.

So-iuy mullet. The gradual naturalization of the species in the Sea of Azov was carried out in 1979–1985. The delivery of so-iuy mullet fry was organized at first from water bodies of Primorye to the Molochny estuary, then the broodstock was formed, and the factory reproduction was mastered. In 1984, the release of vigorous fry began directly in the sea (*Vselentsy v bioraznoobrazii*..., 2010), where in 1989 there was for the first time a strong year class numbering from 50 to 300 million individuals (Pryakhin and Volovik, 1997). In subsequent years, so-iuy mullet intensely spread in the Azov–Black Sea basin and formed a powerful self-reproducing population. In the commercial catches in recent years, it occupies third or fourth place after Black Sea sprat, anchovy, and gobies.

One should note the widespread distribution of so-iuy mullet in the water bodies of the northwestern part of the Azov Sea basin. So the species was noted in the Eastern Sivash, in the Utlyuk and Molochny estuaries, and in the lower reaches of small rivers in the region. The highest number in these water bodies is registered during the autumn period when the species migrates to the rivers for the wintering. This can be seen most clearly in the Obitochnaya and Berda rivers.

The abundance of so-iuy mullet in the Sea of Azov is related to the conditions of its spawning in water bodies having salinity over 17‰ (Kulik, 2001). Thus, the best water body for spawning was for a long time the Molochny estuary. Unfortunately, from 2002, the degree of relationship of the estuary to the sea changed for the worse significantly and was sustained by periodic clearing of the canal. In subsequent years, the irrigation and drainage works were stopped, and the connection of the estuary to the sea was lost. Such a situation led to a decrease in the efficiency of spawning of so-iuy mullet in the Azov region, which was significantly reflected in the volumes of catches in 2012 (Fig. 5a).

Pumpkinseed. Within Ukraine, pumpkinseed is known from the lower reaches of the Danube, the Yalpug and Kagul estuaries, Lake Sasyk, the lower reaches of Dniester (the delta and the Dniester estuary), Odessa Bay, the Tylihul, Berezan, and Dnieper-Bug estuaries, and the floodplain reservoirs of the lower reaches of the Dnieper, and the basin of the Southern Bug (Pavlov and Bil'ko, 1962; Shcherbukha, 1982; Movchan, 2002).

At the beginning of the 21st century, the range expansion of the species is observed to eastern Ukraine, in particular, to the rivers of the northwest part of the Sea of Azov coastal region (Diripasko et al., 2008). The main donor water body became the Kakhovskaya irrigation system, from where the species found its way to the Maly Utlyuk and Molochnaya rivers. The species found the same way, only through the North Crimean Canal, to the water bodies of Crimea. Later on, the delivery of fry together with the stocking material became an additional reason for dispersal. Thus, the facts of release of the species in the ponds of the upper reaches of the Molochnaya River were

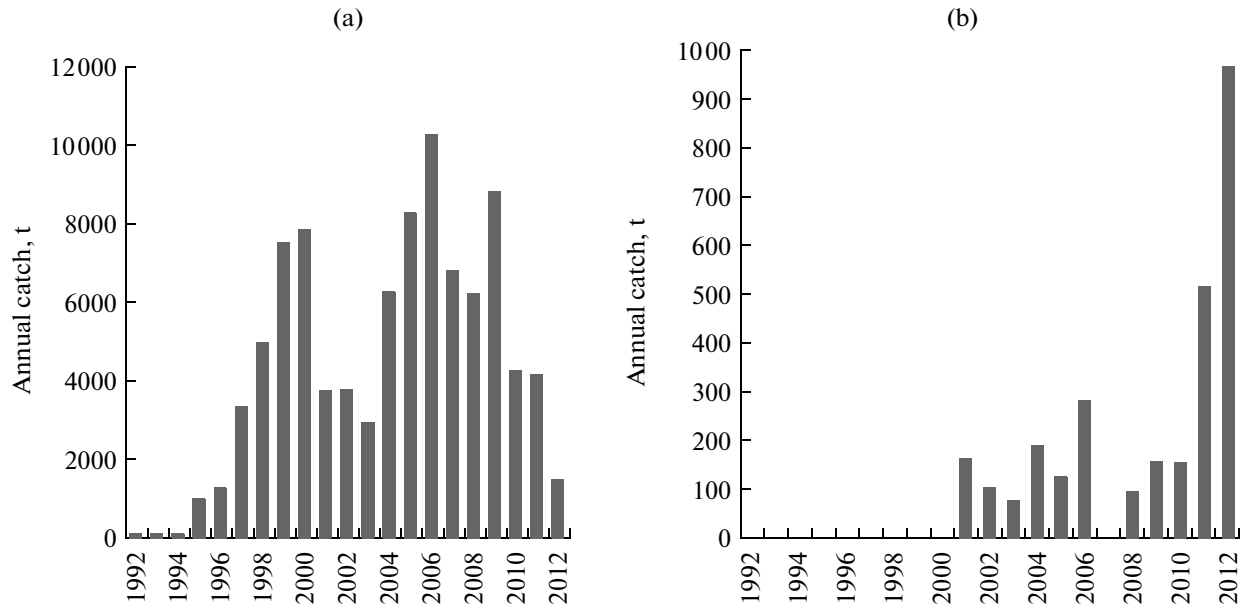

Fig. 5. Dynamics of commercial catches of so-iuy mullet (a) and Prussian carp (b) in the Sea of Azov.

established, as well as in the Berdyansk reservoir on the Berda River.

It should be noted that pumpkinseed after release in a water body intensively settles both on the riverbed and in the tributaries, and thus its abundance sharply increases. So several specimens were noted in the first year of registration in the Maly Utlyuk River in the catch from a gillnet. In the next years, its abundance increased rapidly. The same pattern was observed in the Molochnaya River. Population stabilization was observed for the fifth and sixth years of its habitation in the water body, which is characteristic for invasive species.

In the water areas of the Sea of Azov, pumpkinseed was for the first time found by us in the Utlyuk estuary in 2011 at the salinity of 11.9‰. We consider that the trend of the species distribution in the Azov Sea basin will continue further. The lower area of the Don River may become the most expected place of invasion, although, according to recent investigations (Vasil'eva and Luzhnyak, 2013), this species is not noted in the region. Its penetration into the lower reaches of the Don River is possible along two corridors—from the Seversky Donets River and from Taganrog Bay. A number of other authors point out the same trend of dispersal of pumpkinseed (*Vselentsy v bioraznoobrazii*..., 2010). We consider that the further spontaneous dispersal of pumpkinseed depends on its abundance in the estuarial areas of the rivers and the volume of river flow.

CONCLUSIONS

(1) There are nine alien species in the water bodies of the region of study. The most numerous of them are so-iuy mullet and Prussian carp, which formed self-reproducing populations and are actively used by the fishing industry. It is necessary to assign Chinese medaka, stone moroko, and pumpkinseed to the species which were noted in the basin recently.

(2) The abundance of alien fish species in the studied water areas depends on many factors, the main ones of which are intensity of fishing activities, degree of transformation of hydroecosystems, and intensity of water release into the rivers from canals.

(3) Prussian carp is found everywhere in the rivers of the region of the study, which is confirmed by the average frequency of findings in the catches at the level of 70%. The long-term dynamics of Prussian carp in the catches by different fishing gear in the Sea of Azov shows an increase in the abundance of the species, which is clearly related to a number of environmental factors. In the last decade, a significant increase in the volume of commercial catches has been observed. In 2012, it was more than 950 t.

(4) One should note the widespread distribution of so-iuy mullet in the water bodies of the northwestern part of the Azov Sea basin (Eastern Sivash, Utlyuk and Molochny estuaries) and also in the small rivers of the region, where it is registered in the lower areas. The highest abundance in these water bodies is fixed during the autumn period when so-iuy mullet migrates into the rivers for the wintering. The commercial catches of the species have significant dynamics and depend on the conditions of spawning.

(5) Pumpkinseed is a species distributed most intensely in the Azov Sea basin. Since its first finding, the species already expanded its range in the region and is massively registered today in the Maly Utlyuk, Molochnaya, and Berda rivers and the Utlyuk estuary.

Getting into a water body, pumpkinseed settles intensely both on the riverbed and in the tributaries, and so its abundance sharply increases.

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