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GENERAL BIOLOGY

Ecological Characteristics of the Far Eastern Fish Red-finned Mullet (*Mugil so-iuy* Basilewsky) Acclimated in the Sea of Azov

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Here we summarize the results of long-term studies on the biology of the red-finned mullet (*Mugil so-iuy* Basilewsky) performed in order to fill the gap on our knowledge on one of the bast acclimated species introduced to the Sea of Azov. The new conditions appeared to be favorable for the red-finned mullet: the rates of linear-size and weight growth and early sexual maturation became high; physiological parameters, fertility, and the survival rates of eggs and larva in brackish water changed substantially [1–3]. This allowed the population to grow rapidly and ensured the stabilization of optimal values of biological parameters.

Red-finned mullet living in the Sea of Azov is a mobile fish that may grow as large as 90 cm in length and 12 kg in weight. According to the results of census surveys performed by the Azov and Black Sea Fishery Department and Azov Research Institute of Fishery, the red-finned mullet population is composed of fish from age groups 0^+–9^+. Younger groups are estimated incompletely in the materials of censuses because their biological and behavioral specificity. Usually, their numbers constantly increase with age and peaks at an age of five to six years. The mass inflow of females to the spawning stock occurs at an age of four years. Five- to eight-year-old fish are prevailing in the commercial stock both in the red-finned mullet population of the Sea of Azov and in the native area. Their proportion is, on average, 78%, varying from 75 to 84%.

Red-finned mullet, because of its innate cautiousness, is most accessible for observation in winter, when the fish is the least active and forms dense aggregations. Juveniles usually winter in fresh watercourses with a slow current. Schools of 0^+ fish migrate to river mouths as early as in October. Most juveniles gather in several river depressions, having, if necessary, overcome rapids with an extremely fast current in narrow parts of the rivers. The wintering sites are set shortly before the first frosts in early November. In warm years, wintering is normal even in estuaries with increased water salinity.

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Numerous observations demonstrated that red-finned mullet from the Sea of Azov is cold-resistant and active even at low water temperatures. In contrast to the generally accepted views based on the data on Far Eastern populations, 0^+ red-finned mullet do not remain permanently in stable aggregations even at water temperatures lower than 2°C. The aggregations of juvenile fish may temporarily disperse or move from one wintering site to another. Moreover, fish from strong year classes migrate to open sea in warm winters.

During the daytime, juvenile red-finned mullet are sparsely distributed over fresh watercourses by the sea coast, hiding in plant growths or under fast ice. In the dusk, the fish form schools in deeper parts of the bodies of water. The schools often remain unbroken at the end of wintering, especially on clear days. Not only the shape and area of fish aggregations, but also the frequency distribution of fish in them are seen in the transparent water of small watercourses. If the wind is strong, the schools move along the wind irrespective of the direction of water current. The fish aggregations in watercourses move not only upstream or downstream, but also from one bank to the other. In estuaries, red-finned mullet behaves in the same way. Although red-finned mallet are very cold-resistant, they may die if water is overcooled and poor in oxygen under the ice. In spring, when water is warmed to 4–5°C, the yearlings become more mobile and begin to feed on Chironomidae larvae. The downstream migration of young red-finned mullet to the sea usually occurs at a water temperature of 7–8°C.

In summer, older age groups of red-finned mullet are distributed throughout the aquatic area, including communicating bodies of water and river mouths. In regions with more favorable hydrological conditions and a better developed benthos (food spots), the numbers and population density of the fish are higher. Apart from detritus, the food lump contained protozoans (Foraminifera), small crustaceans (Ostracoda), mollusks (Hydrobia, *Mia arenaria*), polychetes (*Nerieis*), and a few copepods (Copepoda). The fish becomes less active and regroups into schools according to relative similarity in physiological characteristics and linear–

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age parameters when the water temperature is decreased to 8–10°C and ceased feeding entirely at a water temperature about 5°C [2]. The activity and behavior of red-finned mullet varies depending on the period of life cycle (irrespective of water temperature). For example, seine fishing of fat immature red-finned mullet is more successful in the beginning of their wintering at a water temperature of 4–5°C than in spring.

In the northwestern Sea of Azov, red-finned mullet form aggregations earlier. The migration of the fish to the central and southern regions of the sea, where "lenses" of warmer water are preserved for a long time, increases as the coastal waters become colder. The density of these aggregations may be so high that sometimes a 10-min seining brings 7–10 t of fish. After the ice cover becomes stable, the fish is almost permanently immediately under the ice or at least close to it. In these places, the catches are the highest, irrespective of whether seine nets or sweep fishing gear are used (20 and 100 t, respectively).

Observations in natural habitats have shown that the distribution of red-finned mullet in different parts of the area have some specific features depending on the thermal conditions in winter, with different age groups being characterized by different distribution patterns. In general, constant regions and frequency distributions of the fish are characteristic of seasons that had "normal" temperature and wind conditions close to the average ones for many years of observation. The migration of red-finned mullet mainly depends on hydrometeorological conditions and movements of ice fields. Part of the fish almost always remains sparsely distributed and may migrate alternatively from the sea to estuaries and back. Sometimes, the fish stay for a long time in estuaries or forms aggregations in the sea near narrow gulfs.

Recently, progressive freshening of the sea water, warmer winters, and intense fishery have led to a decrease in the density and stability of red-finned mullet aggregations. Note that the red-finned mullet population area has extended to cover an almost entire aquatic area of the Sea of Azov. Large aggregations of the introduced fish species are currently observed in the eastern part of the sea. Apparently, more uniform conditions in different regions in winter and the high adaptability that is inherent in the red-finned mullet favor the formation of local schools.

It has been demonstrated that red-finned mullet respond not only to drastic changes in water temperature, but also to weakest trends of its change. The activity of the fish is increased and the aggregations become less stable in winter if water temperature increases even slightly. The time of formation and the stability of aggregations in different winter months are not constant. In early winter, when the photoperiod is shorter, the aggregations are more likely to form in the dusk or the first half of night. In the second half of winter, red-finned mullet schools are also observed in the daytime; however, the fishing becomes less efficient as the water becomes warmer. The densest aggregations of the fish are formed in calm weather that sets in after storms and at a constant atmospheric pressure, as well as soon before, or in the very beginning of, a fall in temperature. During a full moon, the fish is distributed more sparsely. Red-finned mullet promptly respond to external irritators. The aggregations begin to disperse after a ship comes above them for the first time. The main wintering sites are located far away from navigational routes.

Migrations of red-finned mullet from wintering sites in spring have not been studied sufficiently. As large aggregations break up into smaller schools, visual and sonar observations are ineffective. It is obvious that the migrations of red-finned mullet to spawning grounds occur in different directions. Besides the dispersal over the Sea of Azov and entering adjacent waters, many spawners migrate to the Black Sea through Kerch Strait, which is evidenced both by both the results of visual observations and the results of coastal fishing. In the second half of June and early July, some of the fish that have finished spawning returns from the Black Sea to the Sea of Azov; however, there is no marked postspawning migration. Undoubtedly, the Black Sea population of red-finned mullet is increased every year.

The catch of red-finned mullet in Kerch Strait and the neighboring areas of both seas in spring has dramatically decreased in recent years, notwithstanding the use of mullet trap nets. This is related to both the decrease in the amount and intensity of the red-finned mullet migration to the Black Sea and the change in behavior during spawning migrations. In the initial period of the colonization of the new area, the fish migration routes ran close to the coast even at a water temperature of 8, 9°C. Large schools of red-finned mullet were observed in the Kut (inlet) of Taman Gulf. Then, the fish behavior gradually changed. The aggregations began migrating predominantly through the deep-water part of Kerch Strait and appeared near the coast no sooner than the water warmed to 14–17°C. Therefore, the red-finned mullet fishing intensity dramatically decreased in Taman Gulf.

The fixation of information obtained and teaching acquired reflex acts to other members of the school are characteristic of red-finned mullet. Observations in the southern part of Kerch Strait and near Cape Zheleznyi Rog, where water is sufficiently transparent, showed that red-finned mullet differed from other mullets in behavior. They not merely skirted obstacles (the cape, stone ridges, and trap nets), but sharply turned towards the open sea and did not return to the coastal waters until they had made a long arc. Afterwards, the schools temporarily stopped migrating when they detected a potential obstacle. Individual red-finned mullets moved along the obstacles and then overcame them together. In rivers, juvenile red-finned mullet overcome rapids and small waterfalls.

Thus, the red-finned mullet, a species introduced from the Far East, has acclimated in the basin of the Sea of Azov and the Black Sea and now dominates its ichthyofauna. Utilizing excess organic matter, red-finned mullet prevent mass fish kill and promotes the restoration of ecological balance. This is especially important because of the crisis of the stock of commercially valuable fish because of the decreased natural reproduction and unjustifiably high unregulated fishing. In addition, the generally low use of food resources by benthos-feeders (less than 15%) ensures favorable conditions for feeding and the rapid growth of red-finned mullet as measured by linear sizes and weight, as well as population growth. However, the competition for food with aboriginal species of fish becomes increasingly complex. This, as well as the role of the red-finned mullet in the ecosystem of the Sea of Azov, requires special research.

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