

***Liza haematocheilus* (Pisces, Mugilidae) in the northern Aegean Sea**

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INTRODUCTION

The Mugilidae family consists around the world of more than 72 species from 17 fish genera (Nelson, 2006), with a worldwide distribution. Eight of these species are found in the Mediterranean Sea: *Mugil cephalus* (Linnaeus, 1758), *Chelon labrosus* (Risso, 1826), *Oedalechilus labeo* (Cuvier, 1829), *Liza aurata* (Risso, 1810), *Liza ramada* (Risso, 1826), *Liza saliens* (Risso, 1810), *Liza haematocheilus* (Temminck and Schlegel, 1845) and *Liza carinata* (Ehrenberg, 1836). The first six species are native while the last two are exotic in the Mediterranean. Especially, *Liza haematocheilus* (Redlip Mullet or Haarder), is a euryhaline species inhabiting both freshwater and marine environments. It has confirmed its high ecological plasticity and adaptability to waters considerably differing in both salt content and ion composition so that it can reproduce there and the eggs can be fertilized in the salinity range from 3 to 45‰ (Matishov and Luzhnyak, 2007). This fish can endure the water-dissolved oxygen deficiency (less than 1.0 mg/l), and temperature oscillations from -0.5 to 30 °C (Abrosimova and Abrosimov, 2002), thus being able to winter in cold freshwater (Starushenko and Kazansky, 1996). It has been introduced from seas of the Far East as suitable for aquaculture in the Azov and the Black Seas where the local mullets have suffered greatly from extreme water temperatures and salinities (Starushenko and Kazansky, 1996). Following eight (1972–1980) and six years (1978–1984) of translocations into lagoons of the Black and Azov Seas respectively, together with three years (1984, 1987 and 1989) of releases of fry produced from induced spawning stock, a self-reproducing population has been established (Starushenko and Kazansky, 1996). After collapse in the early 1990's, live fish were released in these installations to the free water. Some of these specimens crossed the Bosphorus, the Sea of Marmara and the Dardanelles and appeared soon after in the Mediterranean (e.g., the Gulf of Smyrna in Turkey (Kaya et al., 1998) and the Thracian Sea in Greece (Koutrakis and Economidis,

2000). During the last few years it has spread progressively and been recorded in several other localities in the northern Aegean Sea (mainly in the Strymon and Nestos estuaries). However, there is no clear evidence that it has established a self-sustaining population.

According to Corsini and Economidis (2007), the species introduced via aquaculture form a new category of allochthonous species which is gradually increasing in almost all of the Mediterranean, mainly due to rearing of exotic species in cages, of careless management in various sea fish farms, the lack of laws or of the enforcement of existing laws and of international rules. In fact, there are some unverified records of the presence in free waters of several such exotic fish and crustacean species such as the fishes *Pagrus major* (Japanese bream), *Liza carinata* (Roving grey mullet), various *Acipenser* species (see Koutrakis and Economidis, 2006), the shrimp *Marsupenaeus japonicus* or fry of native Mediterranean fish, such as *Dicentrarchus labrax* and *Sparus auratus*, reared elsewhere, and exotic eel fry (*Anguilla japonica* and/or *A. rostrata*).

SYNONYMY AND TAXONOMY

Redlip mullet or Primorskiy redlip or haarder was and is still known under various names: *Liza haematocheila* (Temminck and Schlegel, 1845); *Chelon haematocheilus* (Temminck and Schlegel, 1845); *Mugil so-iuy* Basilevsky 1855; *Liza laurvergnii* (Eydoux and Souleyet, 1841) and *Liza menada* Tanaka, 1916. All these names should be placed in synonymy under the generally accepted as valid *Liza haematocheilus* (Temminck and Schlegel, 1845). Actually, Harrison (2004), after an analysis of nomenclature, used the name *Liza haematocheila* which Bogutskaya and Naseka (2004) replaced by the more correct *Liza haematocheilus*.

Another key point is the taxonomy of the species, i.e. the genus under which *Liza haematocheilus* should be classified. According to Harrison (2003), the two genera *Chelon* and *Liza*, having both as types the Mediterranean species *Chelon labrosus* and *Liza ramada*, share many anatomical and molecular characters, but for various reasons it is not expedient to consider them as synonyms at present. The genus *Liza*, which is a specious but probably non-monophyletic assemblage (Harrison and Howes, 1991) and should be split (Ghasemzadeh, 1998), is however kept for nomenclatural stability as adapted by Eschmeyer's *Catalog of Fishes* (online) and FishBase. It seems as if they are using the name *Chelon*, for *haematocheilus*, based on the opinion of Senou (2002).

REDLIP MULLET IN THE SEAS OF THE FAR EAST

This species is native to the Primorskiy Territory of Russia (brackish waters of the Sea of Japan), distributed at the north-eastern Asian coasts, from Peter the Great Bay (Vladivostok, Sedanka R., Suifan upstream to Voroshilov, Tumen'-ula, and other rivers) as far

north as the Amur Liman; through the Korean Peninsula; in Bo Sea, northern China (Fig. 1), to Macao in the south (Berg, 1949; Thomson, 1997; An et al., 2006).

In Peter the Great Bay, the Redlip mullet occurs during the summer in large numbers in near-shore shoals, in estuaries and near river mouths where fish rear and spawn. In the fall, it migrates into rivers and settles down into pits for wintering (Serkov, 2003).

In the Amur Bay (Fig. 1), the spawning of this species proceeds from June until the middle of July (maximum reached by the end of June) at water temperatures of 15.8-20.7 °C, salinity 31.5-32.8 ‰, at depths of 10-35 m. (Mizyurkina, 1984). Furthermore, eggs were recorded at depths from 5 to 20 m at water temperatures of 14-15.8 °C, salinities of 24-33‰ (Mizyurkina, 1984) while the egg diameter varied from 0.85 to 1.05mm (average 0.95mm) and the diameter of the oil drop from 0.35 to 0.55mm (average 0.44mm) (Chesalina, 2000).

Redlip mullet is quite common in the rivers emptying into Peter the Great Bay together with *M. cephalus* (Fig. 1) entering fresh waters while large concentrations of fry (30-60 mm) have been encountered in the mouths of the rivers in August (Berg, 1949). Developing eggs appeared in the beginning of July above the depths of 23-29 m

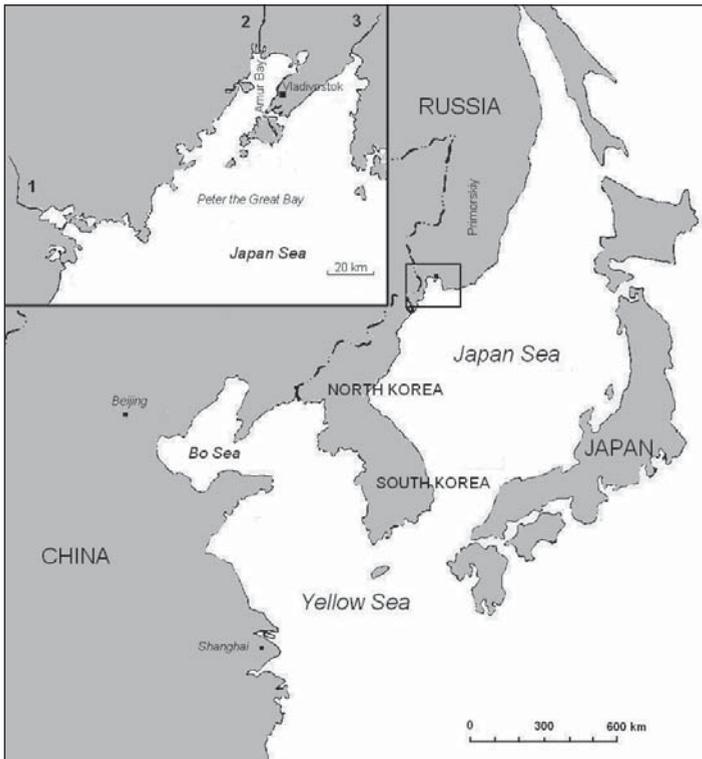


Fig. 1. Schematic map of the native waters of the Redlip mullet and enlargement of the Primorskiy region. (1) Tesnaya river; (2) Razdol'naya river; (3) Artemovka river.

at a surface water temperature of 16.6–17.1 °C. The egg diameter varied from 0.83 to 1.01 mm (average 0.93 mm) and the diameter of the oil drop from 0.34 to 0.54 mm (average 0.44 mm) (Dekhnik, 1951).

In the shores of China the egg diameter has found to vary from 0.84 to 1.09 mm and the diameter of the oil drop from 0.38 to 0.51 mm (Sha et al., 1986). The pelagic larvae of Redlip mullet are typically found in near-shore waters and post-larvae migrate to inshore waters and shallow estuaries (Li, 1992: cited after Liu et al., 2007).

According to Omelchenko et al. (2004) Primorskiy Redlip mullet is represented by four local subpopulations differing in wintering localities and possibly in spawning sites. The extent of isolation or genetic exchange among subpopulations is unknown. The largest subpopulation winters in Tesnaya rivers and spawns in the sea in the southern Khasanskiy region of Primorskiy (Fig. 1). The Razdol'naya subpopulation winters in the Razdol'naya River flowing in the northern Amur Bay and spawns in Peter the Great Bay in the vicinity of Russkii Island (Fig. 1). The Artemovka subpopulation presumably spawns in the same bay, wintering in rivers of the Ussuri Bay (Fig. 1). The Kievka subpopulation winters in the Kievka River (southeastern coast of the Sea of Japan); the locality of its wintering is unknown.

As was reported by Omelchenko et al. (2004) the Far Eastern Primorskiy populations appeared to be genetically homogenous. This can be explained by 1) the absence of strict isolation between them and 2) the similar levels of salinity in the spawning localities of the Sea of Japan, about 30‰.

Redlip mullet originates from an area (Sea of Japan) that experienced extreme changes in water level, especially during the Pleistocene glacial cycles. The Sea of Japan is a semi-enclosed marginal sea, which is distinguished from the other marginal seas of the Western Pacific by its extremely shallow sills. It was closed with long-term isolation from the Pacific Ocean and the East China Sea during glaciation events due to its shallow ledges (< 135 m) and became a freshwater body at least twice (Liu et al., 2007). The population of Redlip mullet could have become isolated in this area and adapted to the great variation of salinity. Adaptation to such changes included hibernation in river depressions during winters, thanks to its ability to store fat (Starushenko and Kazansky, 1996).

REDLIP MULLET IN THE AZOV AND BLACK SEAS

The Azov and Black Seas populations of Redlip mullet started being established after its introduction for aquaculture purposes in the Black Sea in 1972 and in the sea of Azov in 1978 (Starushenko and Kazansky, 1996). The initial population was formed by juveniles captured in the mouth of the Sukhodol (Kangauz) river and in the Ussuri Bay in the Sea of Japan, near Vladivostok (Fig. 1), and transported by airplane to Odessa (Starushenko and Kazansky, 1996). The reason for this introduction was the drastic decrease of the abundance of the valuable local commercial fish species (mainly grey mullets) and the

ineffective artificial propagation attempts in the early 1970s (Zaitsev and Starushenko, 2000; Omelchenko et al., 2004). Since 1984, coastal lagoons of Molochny, Shabolotsky and Burnassk, began to be stocked with fish produced from artificial propagation. It seems that from these lagoons Redlip mullet escaped to the free waters of the Azov and the Black Seas (Starushenko and Kazansky, 1996).

During sampling in the Azov and Black Seas mature or ready to spawn individuals were found but never developing eggs (Chesalina, 2000). Initial data confirming the natural spawning were obtained during June 1989, when in the Molochny estuary (Azov Sea) young individuals were collected at the stage of the laying of scales (Chesalina, 2000) and in 1990 fertilized eggs and larvae were found (Luzhnyak, 2007). However, the first information about the presence of eggs of Redlip mullet in the Black Sea was in 1996 (Chesalina, 1997; Kideys et al., 2000) and proved that this species which was introduced into the northern lagoons during 1972–1986 now spawns along the coasts of the Black Sea.

The acclimatization of the species in these seas (Fig. 2) was completed at the end of the 1980s – beginning of the 1990s – by the formation of a self-reproducing population (Chesalina, 2000). In 1992, Redlip mullet was included into the Inventory of Edible Fishes of the Sea of Azov/Black Sea Basin and in 1993 it was officially permitted to

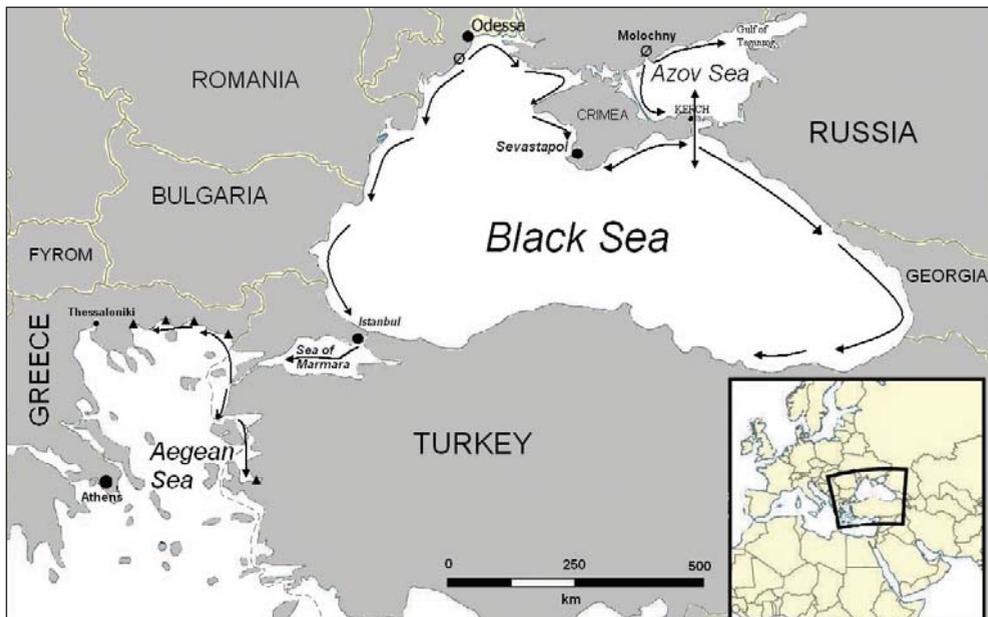


Fig. 2. Schematic map of distribution of Redlip mullet in the Azov and Black Seas and recorded migration paths (→) to the Aegean Sea where the populations appeared. ∅ = the areas where individuals were released into the Azov and Black Seas; ▲ = places where individuals were captured in the Aegean Sea.

catch it commercially (Matishov and Luzhnyak, 2007). At present, the increase in the abundance of the Redlip mullet population throughout the Azov and Black Seas basins has resulted its occurrence in many lagoons, river mouths and coastal areas of Romania, Bulgaria, the Ukraine, Russia, Georgia and Turkey (Fig. 2) and made it one of the most important and common commercial fish, reaching first place in catches of grey mullets, providing a total catch of 12,430 t in 2006 (Abrosimova and Abrosimov, 2002; Anonymous, 2002; Pianova, 2005) and successfully replacing the depleted stocks of the three local mullets (Starushenko and Kazansky, 1996). It is worth mentioning that in native waters (Primorskiy Bay) it did not exceed 500 t. (Sabodash and Semenenko, 1995). Actually, recently in the Turkish coasts of Black Sea remarkable quantities of catches of this fish have been recorded. This fact suggests that the fish should be abundant all along the coast line of the Turkish Black Sea, perhaps even up to the Bosphorus channel (Fig. 2).

Normally developing eggs in different stages were found during June in the Sevastopol region (Black Sea) at water temperatures of 18–20 °C, salinity of 17.6–18 ‰, above the depths of 20–100 m (Chesalina, 2000). In the Southern Black Sea (Okumuş and Başçınar, 1997) Redlip mullet enter shallow waters for feeding and spawning from mid May, where the spawning season extends from the end of May to the middle of July.

In the Azov Sea species spawn in water temperatures ranging from 10.5 to 24.0 °C and salinity from 12 to 17 ‰ (Abrosimova and Abrosimov, 2002), during evenings and night (Chesalina, 2000). The spawning period lasts from April to July. After first spawning in April–May the next oocytes group matures and since the vitellogenesis of mullet is fast, at the end of July they are able to spawn for a second time (Pianova, 2005).

According to Matishov and Luzhnyak (2007) Redlip mullet switched its spawning standards after its acclimation in the Azov Sea and not only winters but also reproduces into rivers and streams with low salinity. This capability to perform spawning migrations to rivers and to reproduce into them has not been previously recorded either in water bodies of the Primorskiy or in the Azov–Black Sea basin (Luzhnyak, 2007). Why did the species adopt so quickly a different reproduction strategy, leaving the open sea for inland waters, while the native mullet species (*L. aurata*, *L. saliens* and *M. cephalus*) did not?

Perhaps the answer to this question is an ecological adaptation of Redlip mullet into the new and changing environment, following a lower level of predation by the alien ctenophore *Mnemiopsis leidyi*. Precisely on the onset (see above) of the Redlip mullet reproduction, in the Azov Sea the pelagic ctenophore *M. leidyi* appeared which was accidentally introduced from the Atlantic Ocean. This ctenophore was present all over the Azov Sea, inhabiting the water column and feeding on plankton, eggs and larvae of pelagic fish. This was very damaging to the Azov Sea fishery, leading to a collapse of anchovy (*Engraulis encrasicolus*) and seriously affecting the kilka (*Clupeonella cultriventris*) population (see Starushenko and Kazansky, 1996). It appeared that the reproduction of Redlip mullet in the Azov Sea was not affected and continued to be successful and adapted to a different spawning environment so that the eggs are not affected from ctenophore predation (Starushenko and Kazansky, 1996).

What about the physiology of this species? Is it able to successfully go through fertilization, incubation of the eggs and survival of the larvae into fresh water? It is known (Bulli, 1994) that the eggs of Redlip mullet may be fertilized in a salinity range of 3 to 45 ‰ but no fertilization occurs in fresh water. Also larvae are capable of adapting to fresh and saline water at the earliest stages of development, since six-day old individuals with swim bladders filled with gas survive direct transfer from seawater (17-19 ‰) to brackish water (5‰), and safely endure the subsequent transfer a day later to fresh (1‰) water (Bulli and Kulikova, 2006).

Is there any evidence that the Redlip mullet reproduces in freshwater? In the eastern part of the Gulf of Taganrog (North-eastern Azov Sea) Redlip mullet reproduces at a water salinity of at least 5.3-6.4 ‰ and in the Don River, Manych River and Ust'-Manych Reservoir from the middle of May to late June in lower salinity levels, between 1.7 to 2.7 ‰ (Matishov and Luzhnyak, 2007). Spawning occurred in the daytime, with the participation of one female and two to three males, at a temperature of 21-22° C in the surface layer of water with a slow or backward current, reaching highest intensity towards 11 a.m. (Matishov and Luzhnyak, 2007; Luzhnyak, 2007).

According to Pianova (2005) Redlip mullet in the Azov and Black Seas presents a protogenic hermaphroditism, since individuals are originally females, two years old juveniles are hermaphrodite and later some fish become males. Histological examinations indicated the absence of male among one-year old fish and that hermaphroditism begins to appear in the gonads of two-year old fish (Mikodina and Pyanova, 2001). Testes of two-year old individuals had a few cytoplasmic oocytes among the spermatogoniums (Pianova, 2005). Most of the above conclusions are based on samples from cooling ponds of a nuclear power station (Kursk).

The Azov and Black Sea Redlip mullet is an intermittent and asynchronous spawner, able to produce multiple portions (usually two batches) of eggs under good environmental conditions. If the food supply is poor, the second batch of oocytes is resorbed, thus giving a better chance to the first batch (Starushenko and Kazansky, 1996; Pianova, 2005).

The eggs of Redlip mullet are spherical and pelagic, bearing one large oil drop. The shell of eggs is thin and is transparent and the yolk homogeneous, and a light yellow color. They are developed on surface water by oil drop upwards. In the Azov Sea, the egg diameter varies from 0.83 to 0.95 mm (average 0.87 mm) and the diameter of the oil drop from 0.41 to 0.47 mm (average 0.44 mm) while in the Molochny estuary (Azov Sea), the place for the initial acclimatization of species and subsequently of its mass spawning, there are (in water salinity of 16-17‰) eggs characterized by greater sizes (0.94 mm) and large oil drops (0.52 mm) (Chesalina, 2000). In the Black Sea (Sevastopol region) the egg diameter varies from 0.87 to 0.97 mm (average 0.92 mm) and the diameter of the oil drop from 0.42 to 0.50 mm (average 0.46 mm) (Chesalina, 1997).

Fry usually winter in freshwater streams with a slow current near the mouth, where the wintering sites are usually set by the first frost in November (Matishov and Luzhnyak, 2007). Juveniles, yearlings, two-year-olds and some of three-year-olds in summer mainly feed in

the shallow coastal seawaters and in near-by estuaries. In autumn, as the water temperature decreases to 10° C, juveniles begin wintering migration into fresh waters, entering the mouth and the lower courses of shallow rivers with a slow current. The wintering takes place in water temperatures of 1.5 to 4.5° C and when the temperature reaches the threshold of 8° C, wintering areas are abandoned as feeding activity commences (Starushenko and Kazansky, 1996). Aged specimen move to the sea for wintering. In general, the mullet groups of mature age feed throughout the Azov Sea area and in the estuaries, going for winter to the central part of the sea (Omelchenko et al., 2004). In spring a considerable part of spawners migrate for reproduction to the saltier Black Sea through the Kerch Strait while the rest remain in the Azov Sea, moving to spawn either to open seawaters or to warm fresh-water areas, such as Khanskoe Lake and Taganrog Bay (Omelchenko et al., 2004; Matishov and Luzhnyak, 2007).

Growing in the new more favorable environment (Azov and Black Seas) the species reached a larger size (up to 80 cm), a rise in weight from 0.96±0.10 kg to 3.56±0.23 kg, fecundity at 22% and a growth rate three times greater than in its area of origin (Sea of Japan). Furthermore, maturity appeared one year earlier, spawning began 1-1.5 months earlier and lasted longer than in the Far Eastern seas. The vitellogenic oocyte diameters increased by 48.2% on the average while a reduction appeared in the diameter of the egg with a relative increase in the size of oil drop, which increases the buoyancy of the egg and contributes to the reproduction of species in waters with lower salinity (Starushenko and Kazansky, 1996; Chesalina, 2000; Pianova, 2005; Diripasko, 2007).

Such an invader species seems to have more influence on the local mullet populations and environmental disturbances in general. We should take into account seriously the parasite fauna carried by any exotic species which may probably affect progressively the local closely related species. Regarding Redlip mullet, the Azov and Black Sea populations being in contact or found in mixed schools with *M. cephalus*, *L. aurata* and *L. saliens* could eventually infect them with *Ligophorus* (Dmitrieva et al., 2007), a gill parasite of Mugilidae family.

REDLIP MULLET IN THE AEGEAN SEA

The following information on Redlip mullet biology is based on a collection of 28 individuals (43-74.4 cm) sampled from 2003 to 2008 between May and February in the northern Aegean Sea (Fig. 2).

Morphology. The species is easily distinguished from other native mullets in the Aegean Sea by its rather emarginated to slight forked caudal fin and the large scales (Fig. 3). These scales and the head shape resemble a carp and this similarity led Greek fishermen to give it the recent common name “sazanokefalos”, which means “carp-shaped mullet”. Additionally, it also has short pectoral fins, a rather small head pointed and flattened dorsally, a yellow iris and six pyloric caeca of approximately equal length.



Fig. 3. Individual of Redlip mullet *Liza haematocheilus* from the northern Aegean Sea.

The lengths, fork length (*FL*), standard length (*SL*), head length (*HL*), distance of the first (*D₁*) and second (*D₂*) dorsal fin together with the parameters of the estimated linear equations between each morphometric character in relation to the total length (*TL*), are given in Table 1.

A detailed morphometric analysis on Aegean grey mullets is given by Minos et al. (1995) for adults and by Katselis et al. (2006) for fry.

The R-squared values (*R*²) showed that there is a strong correlation between each morphometric character and total length (>0.98) except for *HL* (=0.8).

Reproduction. Information on maturity and reproduction period is based on 28 individuals collected from 2003 to 2008 between May and February in the northern Aegean Sea. Summer samples were collected at the entrances of lagoons and across the coast line during a westward migration but each year after October the samples were found only in freshwater bodies that connect to the sea. Female individuals (7) ranged between 47 to 74.4 cm *TL*, while males (20) from 43 to 74 cm *TL*. It is worthy to mention that this size (74.4cm) is closest to the longest record up to now, being 80.0 cm *TL* (Novikov et al., 2002).

Table 1. Parameters from $TL=a + bX$ for each morphometric character (n=22).

	a	b	<i>R</i> ²
<i>FL</i>	-0.021	1.031	0.997
<i>SL</i>	-1.535	0.873	0.982
<i>HL</i>	-1.329	5.077	0.807
<i>D₁</i>	1.254	2.534	0.989
<i>D₂</i>	1.025	1.539	0.991

All the above individuals were ripening, the gonadosomatic index (*GSI*), being usually <1 , while in July of 2006 (Fig. 4) two more ripe individuals (male and female) were caught (*GSI*: 11.2 and 15.5 respectively), indicating the eventuality of a self-reproducing population. The values of the gonadosomatic index for both sexes (Table 2) varied strongly for the same month each year. The highest value for the females was 15.46 and appeared in late July of 2007, while the lowest value 0.35 appeared in September of 2003. Similar values were recorded in the Black Sea while in the Azov Sea and in the native waters of the Primorskiy region the values were much higher, 26.4 ± 3.5 and 35.2 respectively (Okumuş and Başçınar, 1997; Pianova, 2005). For males, *GSI* values in the Aegean Sea were 11.19 in late July of 2007, while the lowest values 0.13 appeared in the same month of 2004. In conformity with our results, in the Azov and Black seas the highest *GSI* values were about the same (Okumuş and Başçınar, 1997; Pianova, 2005). Consequently, reproduction of the species in the Aegean Sea apparently takes place in the summer from May to September with a peak around July. During fall, individuals full of fat move for wintering into inland fresh waters.



Fig. 4. Ripe male (upper) and female (lower) individuals of Redlip mullet *Liza haematocheilus* from the northern Aegean Sea.

Table 2. Monthly variation of gonadosomatic index (*GSI*) for males and females from 2003 to 2008.

Date	<i>GSI</i>		
	n	Male	Female
September 2003	1		0.350
July 2004	3	0.397±0.26	0.733
May 2005	1	1.849	
August 2005	6	0.198±0.02	0.920.09
October 2005	2	0.722	1.093
July 2006	2	11.187	15.457
September 2007	2	0.282±0.0005	
October 2007	2	2.007±0.08	
November 2007	2	1.477±0.4	
December 2007	2	2.002±0.34	
January 2008	3	3.053±0.742	
February 2008	1		2.898

Age structure. For ageing, 21 individuals were used. Annuli of at least three scales from each individual were counted under a light microscope (Leica MZ6). The age composition of the population was found to vary from 3 to 7, the dominant age groups were 4+ (33.3%) 3+ (28.6%) and 5+ (23.8%) years. It is worthy to note that in the sample there were no young individuals (age groups 1 and 2). The scales showed relatively clear annual rings (Fig. 5), allowing accurate aging for the first 7 years of fish.

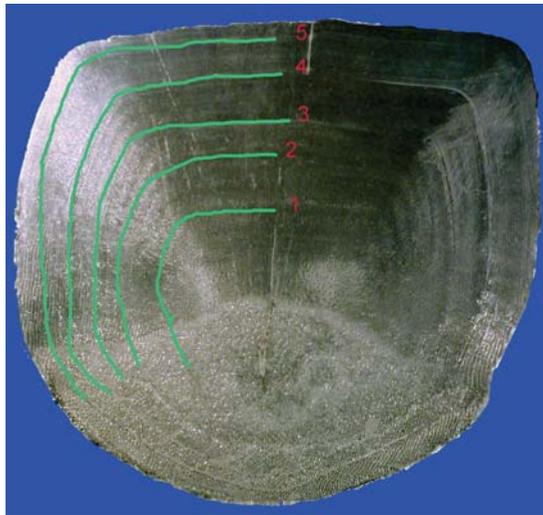


Fig. 5. Scale of Redlip mullet *Liza haematocheilus* from the northern Aegean Sea with five visible growth rings.

Growth. The calculated length-weight relationship from 28 individuals was: $W=0.0002TL^{3.9446}$ ($R^2: 0.96, SE_b: 0.156$), demonstrating an allometric growth ($P<0.05$). Weight ranged from 824 to 5,495 g, this last being greater than the up to now heaviest recorded individual which was 5,000 g (Novikov et al., 2002). Relationships between total scale radius (Rn) and total length (TL) were determined with regression analysis. Back-calculated lengths at the estimated age (L_1 - L_7) of individual fishes were estimated from the total length-scale radius regression ($R^2=0.8$) and are as follows: $L_1 = 11.28$; $L_2 = 24.03$; $L_3 = 37.13$; $L_4 = 46.33$; $L_5 = 55.37$; $L_6 = 63.30$; $L_7=68.65$. It appears that growth is continuous throughout the fish's life. The von Bertalanffy growth equation (VBGE) was adjusted to back-calculated length at age data using the Levenberg-Marquardt method for non-linear regression analysis. The parameters of VBGE for sexes combined are shown in Table 3 while the data set appeared well-adjusted ($R^2=99.94$; $SE=0.626$).

The ratio of L_{max}/L_{∞} was 0.69 and the parameter ϕ' (Munro and Pauly, 1983) was 3.260. In studies in the Black sea (Okumuş and Başçınar, 1997), the age determination was estimated to have a smaller L_{∞} and a greater k and t_0 value, since the von Bertalanffy values were for sexes combined $L_{\infty}=71.8$ cm, $k=0.257$ year⁻¹ and $t_0=-0.562$ and for females $L_{\infty}=97.3$ cm, $k=0.136$ year⁻¹ and $t_0=-1.250$, while the parameters ϕ' were 5.123 and 5.110, respectively. The negative t_0 (age at zero length) values from the Black Sea Redlip mullet indicate that juveniles grow more quickly than the predicted growth curve for adults, and the positive t_0 values from the Aegean Sea population indicate that juveniles grow more slowly (King, 2003). In fact, in the Black Sea samples all age classes were present while from the Aegean Sea young individuals were absent which affected the estimation of the VBGF parameters. Furthermore if this is not due to the lack or low number of young specimen, the alternative explanation could be that in the Mediterranean waters there is not yet successful reproduction.

As mentioned above, the species store fat in their guts and this also observed in the Aegean Sea samples, since all the individuals caught from October till February were full of fat in the guts. This deposition of fat (during autumn and winter) in its body cavity allows a rapid maturation in the spring.

Table 3. von Bertalanffy growth parameters for *Liza haematocheilus* in Aegean Sea.

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower	Upper
L_{∞}	106.67	5.81	90.54	122.81
K	0.16	0.01	0.12	0.20
t_0	0.30	0.06	0.14	0.47

GENETIC STRUCTURE

Azov population. Genetic studies of the species *L. haematocheilus* are few. Omelchenko et al. (2004) conducted a comparative population genetic analysis of the Redlip mullet from the Sea of Japan basin and the Azov Sea basin ranges. The genetic characteristics of the six populations were studied using electrophoretic analysis of fifteen enzymes, encoded by twenty one loci. The aims of this study were the following: a) the genetic characterization of the Far Eastern population, b) the comparison of genetic parameters of the Far Eastern donor and the new Azov populations, in order to detect genetic changes caused by acclimatization and adaptation of the new range and c) the study of genetic differentiation that may have appeared within the Azov population, due to local differences in spawning conditions. The genetic differences between the Far Eastern and the Azov sample groups was found to be highly significant ($Gst = 0.9\%$). The mean heterozygosity per locus was equal in the native and new ranges but a 1.9 fold reduction in the percentage of polymorphic loci and a 1.5 fold reduction in the mean number of alleles per locus was found in the Azov populations. The reduction of these parameters in the introduced mullet may be explained by transplantation of only a part of the original gene pool. Apparently the Azov populations have passed through a dramatic decrease in the effective size (bottleneck effect), which primarily affects the allele number. In the native range, no genetic differentiation among the mullet samples from different areas was found ($Gst = 0.42\%$), whereas in the Azov Sea basin, the samples from spatially isolated populations (ecological groups) exhibited genetic differences ($Gst = 1.38\%$). The genetic homogeneity of the Far Eastern populations may be explained not only by the absence of strict isolation between them but also by the similar levels of salinity in the spawning localities of the Sea of Japan, which are close to the ocean one (reaching 30‰). On the other hand, the genetic divergence of the subpopulations and the excess of heterozygotes at some loci in the Azov population suggest selection processes that formed genetically divergent groups associated with the areas of different salinity in the new range. It is likely that water salinity at the sites of spawning and the egg development may be the major factor of direct or indirect selection providing this divergence.

Another study conducted later by Salmenkova et al., (2007a,b) also investigated the genetic variation of native and acclimatized fish by using Restriction Fragment Length Polymorphism analysis (RFLP) of a mitochondrial DNA fragment containing the cytochrome b gene and the D-Loop. The study had been focused on five out of fifteen endonucleases detected polymorphic sites. In the samples of native and acclimatized Redlip mullet only five common haplotypes were found, whereas ten and three “unique” haplotypes were found respectively in the Far Eastern and the Azov populations.

The haplotype mtDNA diversity was lower in the Azov Sea ($\mu = 6.35 \pm 0.27$) than in the Far Eastern populations ($\mu = 9.14 \pm 0.55$), which is in good accordance with the decrease in the number of polymorphic loci and the mean number of alleles per locus

found in the previous allozyme analysis of these populations. Yet, the reduction of these parameters estimated from the allozyme markers is in accordance with the lower number of haplotypes (three unique haplotypes) and the lower proportion of rare mtDNA haplotypes found for the Azov samples in the RFLP analysis. The mtDNA study demonstrates once again that the Azov populations did pass through a bottleneck, which caused a considerable reduction in the effective population size. In contrast to protein marker data, which showed association with salinity of the spawning localities in the new range, the results of the mtDNA study did not reveal any adaptive character of mtDNA variation in the Azov Redlip mullet.

Turan et al. (2005) studied the phylogenetic relationships of nine mullet species in the Mediterranean Sea by using allozyme analysis and found that *M. cephalus* and *M. soiuy* (= *L. haematocheilus*) clustered together. These are clearly isolated from *Liza*, *Chelon* and *Oedalechilus* genera the highest genetic distance value detected between *M. soiuy* and *L. aurata*. These results, placing *M. cephalus* and *L. haematocheilus* close together, need more confirmation because they suggest a new taxonomical rearrangement which is not justified by other investigations. For instance, Semina et al. (2007) investigating the mitochondrial DNA divergence and phylogenetic relationships in mullets of the sea of Japan (*L. haematocheilus* and *M. cephalus*) and the Azov Sea (*L. aurata* and *M. cephalus*), using PCR – RFLP analysis of three mitochondrial DNA fragments which include 12S/16S rRNA and ND3/ND4L/ND4 genes, found that *L. haematocheilus* and *L. aurata* are clustered together, whereas *M. cephalus* was the most genetically distinct species.

Aegean population. The steady presence of the species in the European seas suggests that it should be recognized and identified among other native mullet. For this purpose a DNA methodology was developed to distinguish fry of six Mugilidae species found in the Mediterranean, namely *M. cephalus*, *L. haematocheilus*, *C. labrosus*, *L. aurata*, *L. ramada* and *L. saliens* (Imsiridou et al., 2007). In higher eukaryotes the 5S rDNA repeats consist of 120 bp highly conserved coding sequences, which are separated from each other by a nontranscribed spacer (NTS) that shows an accentuated length variation (Pendas et al., 1994). The above unit is tandemly repeated, it is located to different chromosome pairs in fish and normally it is species specific (Martins and Galetti, 2001; Martins et al., 2002). The fact that the organization of 5S rDNA presents no intraspecific polymorphism and on the other hand high interspecific variability makes it a very good candidate for comparison of closely related species. For this reason Polymerase Chain Reaction (PCR) amplification of the 5S rDNA gene was used for the identification of the above six species.

Thirty individuals of fry (total length range 20–35 mm) of each of the five most common Mugilidae species (*M. cephalus*, *C. labrosus*, *L. aurata*, *L. ramada* and *L. saliens*) were collected from the coast of Nea Moudania, Northern Aegean Sea, Greece. For the species *L. haematocheilus*, 20 of the individuals mentioned above (sampled from 2003 to 2007 between May and November in northern Aegean Sea), were analyzed. In total 170 individuals of the above six species were analyzed with the PCR technique. The 5S

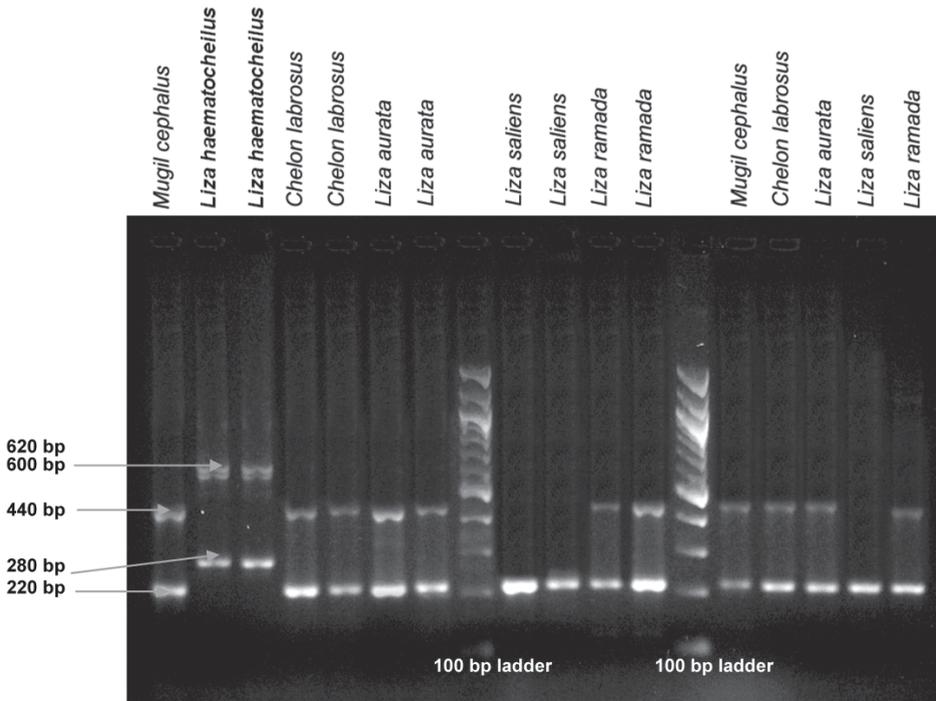


Fig. 6. Electrophoretic analysis on 1.5% agarose gel of the 5S rDNA gene PCR products, obtained from the six Mugilidae species (*M. cephalus*, *L. haematocheilus*, *C. labrosus*, *L. aurata*, *L. saliens* and *L. ramada* – two different individuals per species). The size of the PCR products was checked against a 100 bp DNA ladder.

rDNA gene was amplified successfully in all six species. As shown in Fig. 6, two out of six species revealed species – specific patterns. *L. haematocheilus* gave a pattern of three bands: a band of approximately 280 bp, a band of 600 bp and one of 620 bp. *L. saliens* gave a pattern of one band the size of which was approximately 220 bp. The other four species (*M. cephalus*, *C. labrosus*, *L. aurata* and *L. ramada*) gave a pattern of two bands the sizes of which were around 220 bp and 440 bp. No intraspecific polymorphism was detected, as all the individuals of each species revealed the same PCR pattern.

So *L. haematocheilus* can be discriminated with a simple PCR reaction from the rest of the species, as it reveals a unique PCR pattern.

CONCLUSIONS

Redlip mullet is a highly adaptable, euryhaline fish tolerant of low water temperatures. Usually spawning in lagoons and inshore waters at salinities of 12 to 15‰, it makes

wintering migrations into rivers. In contrast to the other mullet species it can withstand colder waters. It appears to have a remarkably fast growth rate, especially at high water temperatures of 29° to 32°C, making it a very suitable fish for culturing also in warm water. Furthermore, the species have successful adaptation in the Black Sea estuarine complex since: 1) it has a wide range of salinities and/or water temperatures which do not bar this species, 2) the wintering and spawning areas do not coincide with those of the indigenous mullets and 3) within any one estuary, most mullet species avoid interspecific feeding competition by selecting particles of different size (Mariani et al., 1987) or different species present distinct distribution patterns (Almeida, 2003) together with the ability to exploit different eutrophic substrates through their complex pharyngobranchial structure (Capanna et al., 1974).

Growing in the new environment (Azov and Black Seas), considerable adaptive changes were recorded in species biology as compared to the native range. The diet spectrum widened, the rate of growth increased by factors of 1.5–2.0, the size and weight of individuals rose, the time of reaching sexual maturity decreased by a year, spawning began 1–1.5 months earlier and lasted longer, the sizes of the egg and of the oil globule changed and fecundity increased.

Redlip mullet population actually is a commercial species and maintains first place in catches of grey mullets in Azov-Black Sea basin, with a total annual yield of 12,430 t in 2006. Obviously the species presents the character of a true invader with its typical population explosion (invader effect). At the moment it is too early to judge whether this population explosion, as expressed by the high catch, will continue or stabilize. Similar phenomena are appearing in smaller scale in the northern Aegean Sea, where other mullet species are clearly in decline.

Salinity level of spawning sites and subsequent egg development is the most probable factor differentiating local selection during rapid adaptation and naturalization of the acclimatized Redlip mullet population in the Azov Sea providing the genetic divergence of the subpopulations.

Since invader species have more influence on the local populations, parasite fauna carried by the Redlip mullet can progressively affect local closely related species (*M. cephalus*, *L. aurata* and *L. saliens*) who are in contact with this species, possibly infecting them with a gill parasite of the Mugilidae family such as *Ligophorus*.

Starushenko and Kazansky (1996) suggested that the oceanic salinity of water and mild climate of the Mediterranean probably do not pose an obstacle for this species, which might continue to expand its area of distribution towards the Strait of Gibraltar and even beyond, after flooding the Mediterranean. However the westward spreading of the species seems to be not so fast. Maybe there are problems in reproduction; this supposition is reinforced by the lack from the Aegean population of fry and/or juveniles.

The species has appeared in the Aegean Sea since 1998 and it is estimated that it is not yet very abundant. The species appears in coastal areas near estuaries from May to November. During the fall, individuals move into inland waters for the winter (records

were obtained in winter from Lake Vistonis). During this period, the species seems to store fat in its gut, thus making possible a rapid maturation in the spring. The fact of relatively few and large individuals caught and the lack of fry and juveniles of the species across the Aegean Sea indicates that so far it has not been established a self-sustaining population and probably that it is adults who frequent this area for feeding.

Finally, this new invader species in the Black Sea-Mediterranean environment represents an unpredictable prospect. The more negative result would be the successful adaptation of the species in the Mediterranean and the replacement of all or several native mullet. But for this perspective there is not any serious evidence at the moment.

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