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MULLET FRY (MUGILIDAE) IN COASTAL WATERS OF MONTENEGRO, THEIR SPATIAL DISTRIBUTION AND MIGRATION PHENOLOGY

B. MIĆKOVIĆ[1], M. NIKČEVIĆ[1], A. HEGEDIŠ[1,2], S. REGNER[1], Z. GAČIĆ,[1] and JASMINA KRPO-ĆETKOVIĆ[2]

[1]*Institute for Muldidisciplinary Research,* 11000 Belgrade, Serbia
[2]*Faculty of Biology, University of Belgrade,* 11000 Belgrade, Serbia

Abstract – Three localities, representing three distinct coastal areas, were investigated: 1. the mouth of the Sutorina River; 2. the mouth of the Jaška River; 3. the mouth of the Bojana River (right branch). Regarding the composition of young mullet assemblages, *Lisa saliens*, *Lisa ramada* and *Lisa aurata* were dominant at the first locality; *L. aurata* and *Chelon labrosus* at the second; and at the third *L. ramada* was clearly dominant, *Mugil cephalus* occupied the subdominant position, while *L. aurata* was absent. The seasons of the first appearance of migratory fry were October, April, November, October and July, for *M. cephalus*, *C. labrosus*, *L. ramada*, *L. aurata* and *L. saliens*, respectively. Migratory periods varied from 2 (*C. labrosus*) to 7 (*L. ramada*) months.

Key words: Mullet fry, distribution, migration, phenology

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INTRODUCTION

The Montenegrin coast extends in a northwest-southeast direction, between 41o 51'- 42o 51' N, and 18o 30'- 19o 20' E, with a coastline of approximately 294 km of which around 106 km belong to the Bay of Kotor. One of the characteristics of the area is the presence of numerous small streams that flow directly into the sea, as well as a particularly well-developed hydrographic network around the Boka Kotorska Bay. The Bojana River represents the only large body of running water in the entire region. The terminal courses of these rivers are estuaries inhabited by complex fish communities composed of juveniles of the euryhaline species, which use these habitats as nursery grounds (Mićković et al., 1994; Hegediš et al., 1997). Among these species, mullets (Mugilidae) are especially numerous.

Mullets are of great economic importance, both from the fishery and the aquaculture points of view. Mullet farming has been practiced worldwide for centuries, especially in the Far East and in the Mediterranean (Liao, 1981; Nash and Koningsberger, 1981). However, the cultivation methods for mullet are still of extensive pattern, based on the capture of fry in their natural habitats (Liao, 1981; Crosetti and Cataudella, 1994). It is this fact that makes it imperative to acquire the knowledge about the migratory phenology and spatial distribution of the fry in regions with appropriate conditions for lagoon fish culture.

Along the coast of Montenegro, several localities are exceptionally suitable for lagoon farming, but this type of aquaculture is still lacking (Morović, 1974; Kinne and Rosenthal, 1977; Borović et al., 2000). Also, data on the basic ecology of mullet species' fry are scarce and fragmentary (Mićković et al., 1994; Hegediš et al., 1998). This study is an attempt to identify in detail the time of appearance and the spatial distribution of the fry of five common mullet species along the coast of Montenegro.

MATERIAL AND METHODS

In the course of a long-term investigation of mullet fry in Montenegro (August 1990 - April 2001), field

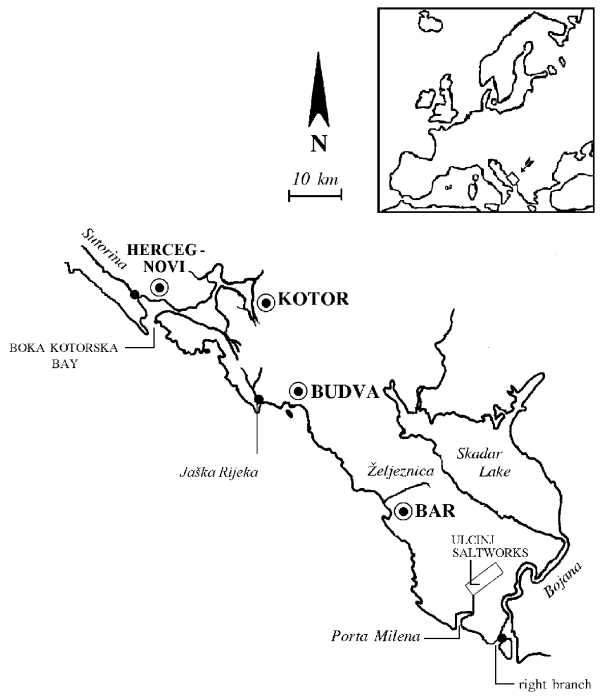

Figure 1. Study area: ● - sampling points.

studies were conducted on 28 occasions at three localities (Fig. 1): 1) the mouth of the Sutorina River, 2) the mouth of the Jaška River, and 3) the mouth of the right branch of the Bojana River. The mullet juvenile forms (fry and juvenile) were captured by a beach seine (20 x 2 m, 2 m codend; 1 x 1 mm mesh size). A total of 7106 specimens were caught and immediately fixed in 70% ethanol. The total and standard length (TL, SL) in millimeters (± 0.1 mm), and weight in grams (± 0.01 g) were measured for each fish. Species identification was performed according to Perlmutter et al. (1957), Zismann (1981) and Reay and Cornell (1988). From the total sample, 5845 specimens belonged to the fry stage. The term fry was applied, according to Zismann (1981), to specimens ranging from the post-larval stage to the stage characterized by TL = 60 mm. According to Zismann and Ben-Tuvia (1975) mullet juveniles belong to three growth categories: a) TL ≤ 30 mm, fry just entering coastal waters, b) 30.1 mm < TL ≤ 60 mm, fry most appropriate for aquaculture initiation, and, c) TL > 60 mm, strong juveniles with high swimming performances, capable of avoiding net catching. The terms migratory fry, sub-juvenile fry and juveniles have been applied for TL ≤ 30 mm, 30.1 mm < TL ≤ 60 mm, and TL > 60 mm size classes, respectively.

The spatial distribution of mullet species was determined according to their relative abundance in the samples for each locality, regardless of the growth category. To determine migration phenology, only the data on the fry developmental stages were analyzed. The share of each fry growth category was determined in monthly samples and subsequently, the migratory phenology was defined.

Water temperature and conductivity were measured when fishing using portable WTW instruments. Both indicators were measured at surface and bottom strata. Recorded conductivity values were used for salinity estimates, applying the formula:

$S = 0.4107 * C^{1.11951}$ (S - salinity ‰, C-conductivity, mS/cm).

RESULTS

The seasonal variations of water temperature and salinity are given in Table 1. Brackish water conditions characterize the mouth region of the

Table 1. Ranges of water temperature and salinity recorded during the entire study period: T_s – surface temperature, T_b – bottom temperature; S_s – surface salinity, S_b – bottom salinity. Values in brackets were observed on one occasion under the conditions of the strong southern wind.

Locality/indicator	Sutorina	Jaška River	Bojana
T_s (°C)	10.0 – 24.9	10.1 – 24.9	4.8 – 25.0
T_b (°C)	10.2 – 25.9	10.8 – 26.2	4.8 – 24.0
S_s (‰)	0.19 – 11.10	0.28 – 7.88	0.11 – 1.42 (8.92)
S_b (‰)	0.19 – 35.30	0.28 – 32.05	0.11 – 2.60 (18.84)

Table 2. Sample size and composition: mf – migratory fry, TL ≤30 mm; sj – sub-juvenile fry, 30.1 mm ≤ TL < 60 mm; j – juvenile, TL > 60 mm.

	Size classes			
Species	mf (n)	sj (n)	j (n)	Σ n
Mugil cephalus	498	152	12	662
Chelon labrosus	365	474	331	1170
Liza ramada	1564	622	345	2531
Liza aurata	525	580	448	1553
Liza saliens	515	550	122	1187
Oedalechilus labeo	0	0	3	3
Σ n	3467	2378	1261	7106

Sutorina and Jaška Rivers. The salinity varies considerably with season, being lowest during periods of rainfall. The stratification of salinity and temperature is distinct throughout the rest of the year. The Bojana River, with the nearby marshlands, represents the largest and most intricate coastal water system in the area. Since shallow zones with weak water current represent typical mullet fry habitats, our studies were focused on the river bank zone up to the depth of 1.5 m. As a result of the high freshwater inflow and the low tide, the salinity is permanently low in this river section, even inside the river mouth. Oligohaline conditions were recorded only at the peak of the dry season. Due to the influence of strong southern winds, mesohaline conditions occur occasionally. As an effluent of Lake Skadar, and due to its cold-water tributary the Drim River, the thermal regime of the Bojana River is strongly influenced by these water-bodies, the influence of the latter being especially apparent during the winter.

The presence of juvenile stages of all six Adriatic mullet species was established at the investigated localities (Tab. 2). A total of 5845 (83.14%) specimens out of 7106 sampled young

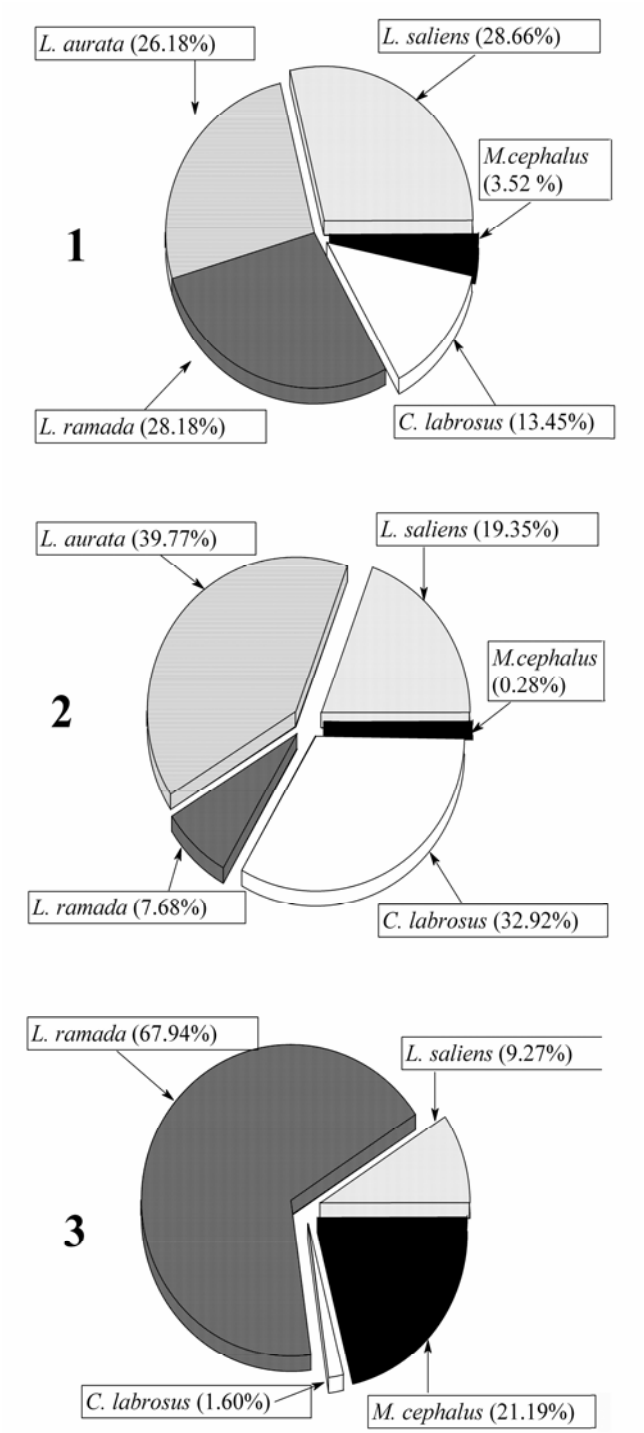

Figure 2. Spatial distribution of young mugilids: 1- Sutorina; 2 – Jaška River; 3 – Bojana River.

mugilids belonged to the fry category. The proportions of migratory fry, sub-juvenile fry and juvenile size classes were 49.34%, 33.80%, and 16.86%, respectively. As regards the species contribution in the whole sample, this was 9.32%, 16.46%, 35.62%, 21.85 %, and 16.70 % for *M. cephalus*, *C. labrosus*, *L. ramada*, *L. aurata*, and *L. saliens*, respectively. Since only 3 specimens of *O. labeo* (0.04%; two specimens at the mouth of the Sutorina River and one at the mouth of the Jaška River) were caught during the entire period of research, this species was excluded from further analyses. Moreover, concerning its biology, this species proved unsuitable for aquaculture purposes (Perlmutter et al., 1957; Morović, 1974).

Figure 2 displays the data on the spatial distribution of young mugilids along the coast of Montenegro. At the terminal parts of the Sutorina and Jaška Rivers, the permanent presence of 5 mugilid species was recorded. Among the mugilids at the first locality, a marked dominance of species from the genus *Liza* was observed. Practically equal contributions were established for *L. saliens* (28.66%), *L. ramada* (28.18%) and *L. aurata* (26.18%). *Chelon labrosus* (13.45%) has an intermediate position, while *M. cephalus* (3.52%) can be considered as a rare species. At the mouth of the Jaška River, among the analyzed mugilids, *L. aurata* and *C. labrosus* represented the dominant and subdominant species. With a relative abundance of 19.35%, *L. saliens* was intermediate and *L. ramada* a relatively rare species in the area. According to our findings, *M. cephalus* inhabits waters at this locality only occasionally. In the course of the study, four mullet species were

Table 3. Time of the first appearance of the mullet fry in coastal waters of Montenegro estimated according to the size class distribution and their relative abundance: mf – migratory fry ≤30 mm; sj – 30.1 mm < sub-juveniles ≤60 mm; (-) – absent; n – monthly sample size.

Species	*Mugil cephalus*			*Chelon labrosus*			*Liza ramada*			*Liza aurata*			*Liza saliens*		
Season	mf (%)	sj (%)	n	mf (%)	sj (%)	n	mf (%)	sj (%)	n	mf (%)	sj (%)	n	mf (%)	sj (%)	n
January	-	-	-	-	-	-	100	-	44	-	-	-	-	-	-
February	100	-	1	-	-	-	100	-	279	-	100	5	-	100	3
March	-	-	-	-	-	-	100	-	411	1.6	98.4	185	-	100	7
April	-	100	1	100	-	2	75.5	24.5	452	28.9	71.1	166	-	-	-
May	-	100	109	99.5	0.5	365	8.0	92	338	-	100	258	-	100	55
June	-	-	-	-	100	93	-	100	155	-	100	12	-	100	11
July	-	-	-	-	100	163	-	100	3	-	-	-	100	-	37
August	-	-	-	-	100	191	-	-	-	-	-	-	90.0	10.0	221
September	-	100	1	-	100	12	-	-	-	-	-	-	90.6	9.4	96
October	60	40	5	-	100	13	-	-	-	100	-	42	50.3	49.7	147
November	92.5	7.5	523	-	-	-	100	-	221	99.5	0.5	431	24.4	75.6	483
December	100	-	10	-	-	-	100	-	283	50	50	6	-	100	5
Σ n		650			839			2186			1105			1065	

recorded at the mouth of the right branch of the Bojana River. Not a single specimen of *L. aurata* was caught during the entire study period. Among the determined species *L. ramada* was clearly dominant; *M. cephalus* occupied the subdominant position, while *L. saliens* and *C. labrosus*, based on their relative abundance, represented rare and occasional species.

The migration phenology was estimated according to the growth category of the fry caught. Table 3 contains data on the seasonal and size class distributions of mullet fry in waters of the coastal zone of Montenegro. Seasons follow in their calendar sequence, regardless of the year of investigation. For the first time, regarding the investigated area, the presented results included an entire one-year cycle, allowing a detailed estimation of the migratory periods. According to our results, the migratory periods of the mullet fry are as follows: *M. cephalus* - October to February; *C. labrosus* – April and May; *L. ramada* – November to May; *L. aurata* – October to December; *L. saliens* – July to November.

DISCUSSION

Our investigations confirmed that all six Adriatic mullet species inhabit coastal waters of Montenegro. The capture of *O. labeo*, although occasional, was of particular interest since this species has been described as the only typically stenohaline species among the Mediterranean mugilids (Perlmutter et al., 1957; Herzberg and Pasteur, 1974; Ben-Yami and Grofit, 1981). Since our finding disagrees with this generally accepted view, it deserves a thorough consideration in future studies.

Each size class represents an important phase of the life cycle, from both the viewpoint of the ecology of the species and its applicability to aquaculture. The migratory fry size class (TL≤ 30 mm) includes the fry just entering coastal waters (Perlmutter et al., 1957; Anderson, 1958; Katavić, 1980; Nash and Koningsberger, 1981; Reay and Cornell, 1988; Koutrakis et al., 1994). At this growth stage, fry form large homogenous schools occurring in shallow waters near the surface; their swimming performances are weak and feeding is zooplanktivorous (Odum, 1970; Vallet et al., 1970; Albertini-Berhaut, 1973; Zismann and Ben-Tuvia, 1975; Brusle, 1981; Gisbert et al., 1995, 1996). Large schools of sub-juvenile fry (30.1 mm ≤ TL <60 mm) inhabit shallow habitats moving at the bottom in search for food. This size class is a transitional phase to juvenile developmental stage and is characterized by completion of morphological and anatomical differentiation (Zismann, 1981). Fry are omnivorous, feeding on animal and plant-based diets, as well as on detritus (Suzuki, 1965; Brusle, 1981; Eggold and Motta, 1992; Smith and Deguara, 2002). Also, their swimming performances are not fully developed. Fry of this size are usually taken in large numbers for the stocking of freshwater or brackish water ponds (Zismann and Ben-Tuvia, 1975; Liao, 1981; Ben-Yami, 1981; Crosetti and Cataudella, 1994). The juvenile size class (TL >60 mm) includes strong specimens with high swimming performances capable of avoiding net catching. Their schools are small and scattered in appearance.

Mullets in general tolerate a wide range of salinity (Thomsnon, 1966; Bardach et al., 1972). Although euryhaline, members of the family Mugilidae differ in their affinity to certain salinity ranges, which in turn influence the habitat selection and, consequently, their distribution patterns. Influence of abiotic factors on the distribution of young mugilids has been described by several authors (Perlmutter et al., 1957; Lasserre and Gallis, 1975; Brusle, 1981; Cardona, 2000, 2006). They pointed out that salinity is the key factor that determines the distribution pattern of young mugilids. *M. cephalus* and *L. ramada* prefer oligohaline and freshwater conditions, *C. labrosus* and *L. saliens* show a preference for intermediate mixohaline conditions, while *L. aurata*, the least tolerant species, has an affinity for more maritime conditions. With respect to the composition of young mullet assemblages at individual localities,

both qualitative and quantitative, it is evident that their distribution follows the described pattern.

Along the coastal zone of Montenegro, from an ecological point of view, three specific areas can be distinguished: a) the coastal area of the Boka Kotorska Bay, b) the central coastal area, and c) the southernmost area. The Boka Kotorska Bay is under the strong influence of fresh waters during the rainy season; the central coastal zone is exposed to the open sea with negligible freshwater influence; the southern area is characterized by a permanent strong influence of the Bojana River. Each of the investigated localities is representative of one of the recognized areas, thus reflecting the distribution of young mugilids over the entire coastal zone.

The first appearance of the mullet fry in coastal waters is related to the spawning period and the distance of the spawning grounds from the coast. Mullet species spawn in off-shore waters and their spawning periods in the Adriatic are as follows: *M. cephalus* – July to October; *C. labrosus* – winter; *L. ramada* – fall and winter; *L. aurata* – July to November; *L. saliens* – summer and fall (Jardas, 1996). Upon reaching the post-larval stage, they actively migrate to the coastal waters, including estuaries and rivers. Fry recruitment to estuaries is seasonal and they are approximately 2 months old at the time of appearance (Crosetti and Cataudela, 1994). Along the coast of Montenegro, it was found that of the five common species, fry of approximately 30 mm TL appear during definite months of the year. The most extended period of migration was recorded for *L. ramada* (7 months duration), while the shortest one was recorded for *C. labrosus* fry (2 months). It seems that the second run of *L. aurata* migratory fry (March and April) occurs with two months' delay in relation to the main migratory period. Actually, these fry represent the slow-growing individuals that had spent the winter in the coastal locality, thus avoiding lower salinity conditions in the river mouths during the rainy season. Later, with the termination of rainfall, they move from the surrounding coastal sea into the river mouths. Generally, the timing of the seasonal occurrence of mullets in the coastal area of Montenegro follows the same sequence described for other Mediterranean regions, with 1-2 month variation (Perlmutter et al., 1957; Zismann and Ben-Tuvia, 1975; Katavić, 1980; Rossi, 1986; Koutrakiset al., 1994; Crosetti and Cataudella, 1994; Koutrakis, 2004). Rossi (1986) reported that different times of in-shore migration for the same species in different areas are not only the result of environmental differences, but also dependent upon the distance from the spawning area.

From an aquacultural point of view, the southernmost area of the coast of Montenegro could be designated as an important potential resource of *M. cephalus* and *L. ramada* fry. Furthermore, it is also possible to collect the second species within the Boka Kotorska Bay. The Boka Kotorska Bay and the central coastal area represent the locations where the fry of the other three species of mullets could be collected.

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МЛАЂ СКАКАВИЦА (MUGILIDAE) У ПРИОБАЛНИМ ВОДАМА ЦРНЕ ГОРЕ, ЊИХОВА ПРОСТОРНА ДИСТРИБУЦИЈА И МИГРАЦИОНА ФЕНОЛОГИЈА

Б. МИЋКОВИЋ[1], М. НИКЧЕВИЋ[1], А. ХЕГЕДИШ[1,2], С. РЕГНЕР[1], З. ГАЧИЋ[1] и ЈАСМИНА КРПО-ЋЕТКОВИЋ[2]

[1]*Институт за мултидисциплинарна истраживања,* 11000 Београд, Србија
[2]*Биолошки факултет, Универзитет у Београду,* 11000 Београд, Србија

Као репрезенти три карактеристична приобална подручја, обављена су истраживања три локалитета: 1. ушће Суторине, 2. ушће Јашке ријеке, 3. ушће Бојане (десни крак). У саставу јувенилних популација скакавица *L. saliens*, *L. ramada* и *L. aurata* представљале су доминантне врсте у водама првог локалитета; у водама другог локалитета *L. aurata* и *C. labrosus* биле су најзаступљеније врсте; на ушћу Бојане *L. ramada* била је изразито доминантна, *M. cephalus* представља субдоминантну врсту, док присуство *L. aurata* није забележено. Прва појава миграторне млађи била је везана за следеће месеце: *M. cephalus* – октобар; *C. labrosus* – април; *L. ramada* – новембар; *L. aurata* – октобар; *L. saliens* – јул. У зависности од врсте, дужина миграционих периода варирала је од 2 (*C. labrosus*) до 7 (*L. ramada*) месеци.