

Maturation, reproduction and recruitment of the sand smelt, *Atherina boyeri* Risso, 1810 (Pisces:Atherinidae) in the estuary of Mala Neretva River (southeastern Adriatic, Croatia)

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*Characteristics of maturation and recruitment of the sand smelt, *Atherina boyeri*, from the Mala Neretva River estuary in the southeastern Adriatic, Croatia in 2001/2, are presented. The average gonadosomatic index (GSI) during a 12-month period was 1.59% for females and 2.1% for males. The highest value was in April, 5.4% for females and 4.7% for males. The smallest mature female was 5.2 cm total length. Fifty percent of the females were mature at 7.75 cm total length. New juveniles began to recruit in June and July and later appeared in fewer numbers. In general, the GSI was lower than in other sand smelt populations. The reasons are difficult to determine but might be partly explained by the high and unpredictable temperature and salinity variations in the researched area that have led to previously described disturbances of the sand smelt life cycle, as in feeding and a high incidence of spinal deformities.*

Key words: sand smelt, *Atherina boyeri*, maturation, recruitment, Mala Neretva River

INTRODUCTION

The sand smelt, *Atherina boyeri* Risso 1810, is common in the Mediterranean and adjacent seas and in the northeast Atlantic from the Azores to the northwestern coast of Scotland (QUIGNARD & PRAS, 1986). It is a small, short-lived, euryhaline

atherinid fish that mainly inhabits coastal and estuarine waters including coastal lagoons, salt marshes, and, more rarely, inland waters, over a wide range of salinities from freshwater to hypersaline conditions (HENDERSON & BAMBER, 1987). Sand smelt mature in the first year of life and spawn in the second half of spring

and the beginning of summer (JARDAS, 1996; PALLAORO *et al.*, 2002). The spawning season in brackish lagoons of southern France extends from February to September, with a peak in April-June (TOMASINI *et al.*, 1996).

BARTULOVIĆ *et al.* (2004a) presented data on the diet and BARTULOVIĆ *et al.* (2004b) on the age, growth, mortality, and sex ratio of the sand smelt from the Mala Neretva River estuary. The sand smelt usually inhabits ecosystems with unstable living conditions where temperature, salinity, turbidity, currents, and quality and quantity of food greatly vary. Therefore, reproduction characteristics are specific to each population. The recruitment process is affected by unstable conditions (BARTULOVIĆ, 2003) and success depends on the availability of suitable surfaces, such as sublittoral filamentous algae, for egg attachment (HENDERSON *et al.*, 1984).

In this study we present characteristics of maturation and recruitment of the sand smelt from the Mala Neretva River estuary in the southeastern Adriatic, Croatia.

MATERIAL AND METHODS

The present study was carried out in the estuary of the Mala Neretva River situated on the southeastern Adriatic coast (Fig.1). The mouth of the river is closed by a dam that prevents the inflow of salt water into the upper agricultural part of the estuary. The sampling site was downstream from the dam, where marine conditions dominate but the inflow of fresh water and polluted water pumped from the agricultural complex is constant. This leads to daily and seasonal changes of temperature and salinity at the sampling site. Average monthly temperatures varied from 9°C in February to 25°C in August. The winter water temperatures were affected by the inflow of the fresh water that was colder (7.4°C) than the sea water (11.4°C) during this period. Salinity varied from 4 to 38 psu during the winter but, due to the low freshwater inflow, only from 30 to 38 psu in the summer.

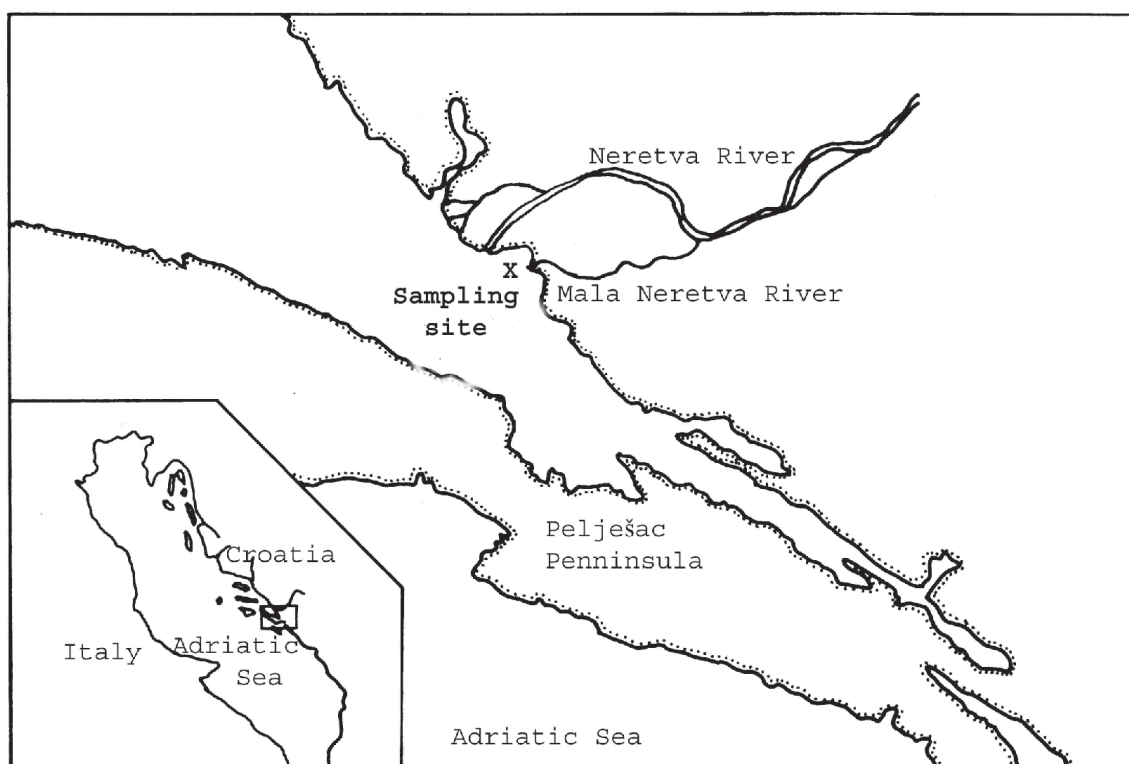


Fig. 1. Map of the study area

Atherina boyeri (n = 1200) were collected monthly from March 2001 to February 2002 at the station near the dam. The fish were collected with a small net (5 mm mesh) used locally for the sand smelt fishery. It is one square meter of net on a metal frame, connected by ropes to a main rope; when the fish appear above the net, it is lifted out of the water. Temperature and salinity were measured before sampling with a mercury thermometer and a laboratory inductive salinometer. Fresh specimens were transported to the laboratory where total (TL) and standard length (SL) were measured to the nearest 0.1 mm and body weight to the nearest 0.01 g. Gonads were examined to determine sex and reproductive stage.

Gonads from all 1068 sexually mature fish were dissected, dried from water and blood using paper, and weighed to the nearest 0.01 g. The gonadosomatic index (GSI) was calculated as:

$GSI = \text{wt gonads} / \text{total wt} \times 100$ (WOOTON, 1990). The GSI was computed for each month and in total, for females, males, and both sexes together.

RESULTS

The smallest mature female was 5.2 cm (TL) and 50% of the females were mature at 7.75 cm (TL). Maturation, represented by the percentage of females with a GSI above the average yearly GSI of the total female sample, significantly correlated with total length ($r^2=0.887$; Fig. 2).

The average GSI during the 12-month period was 1.59% for females and 2.1% for males. The GSI began to rise in March (1.55% for females and 4.6% for males; Fig. 3), peaked in April (5.4% for females and 4.7% for males), and dropped in June (females 2.27% and males 3.1%) and July (females 2.54% and males

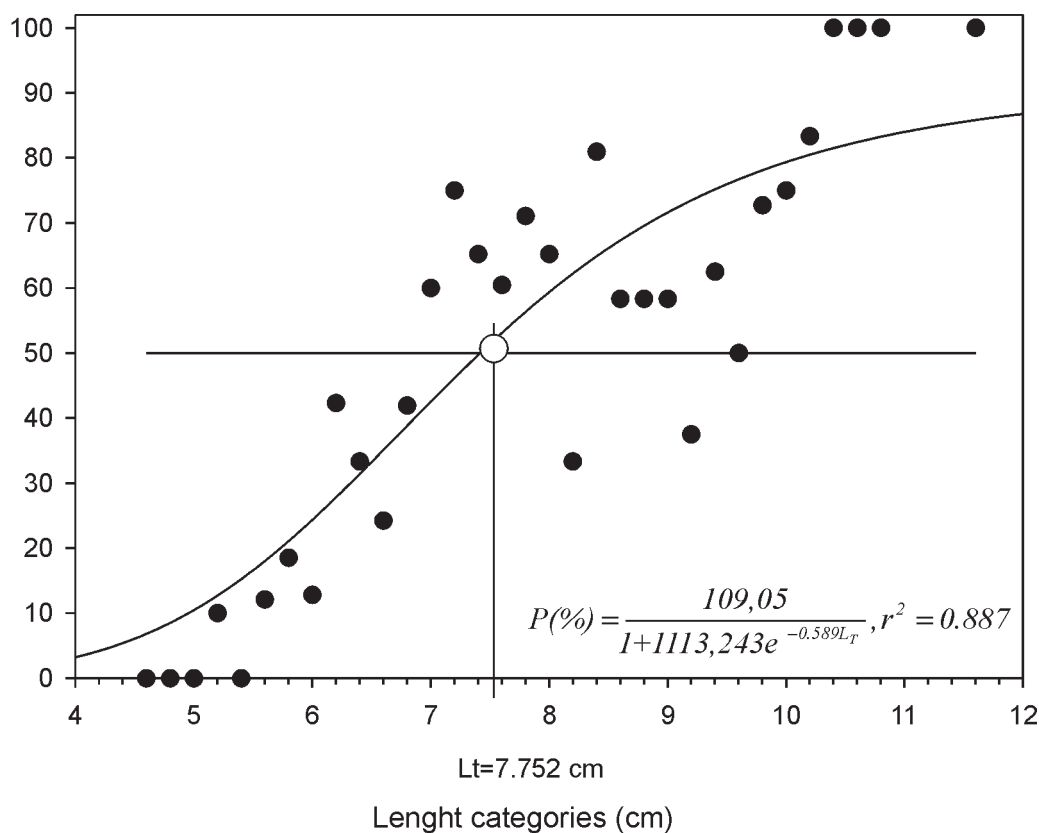


Fig. 2. Percentage and length of mature sand smelt females from the Mala Neretva River. Vertical bar represents length at which 50% of the females in the sample were mature

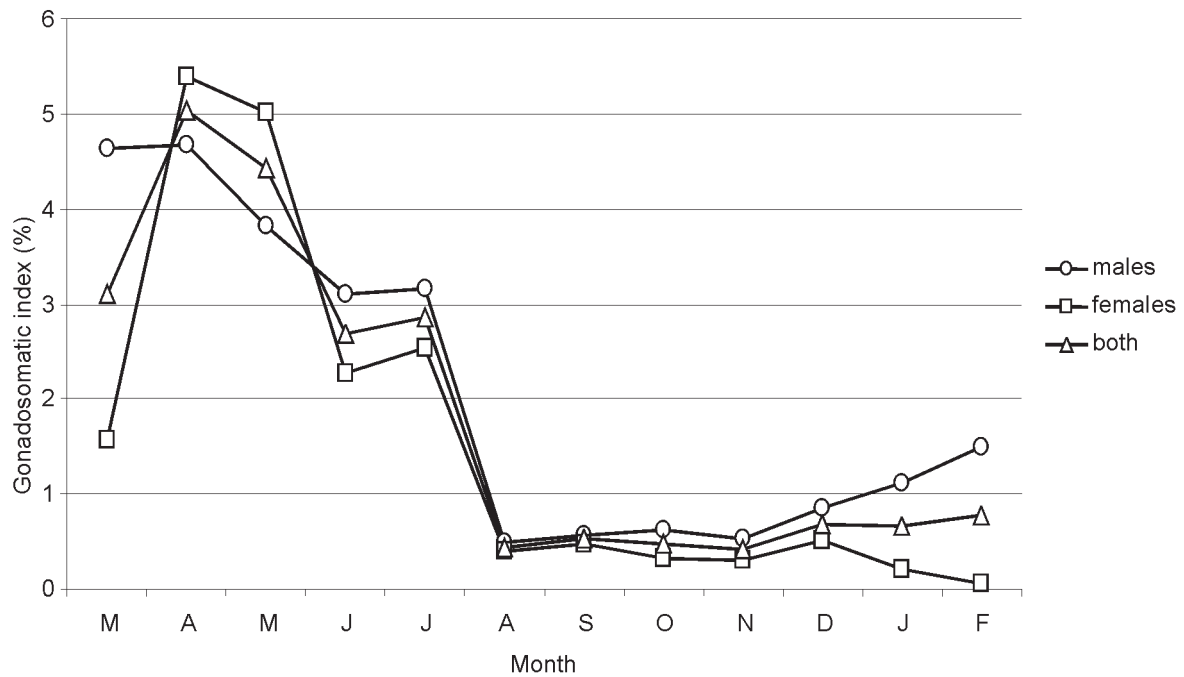


Fig. 3. Average gonadosomatic index of males, females, and both sexes in monthly samples of sand smelt from the Mala Neretva River

3.17%). During March-May, over 90% of all females were mature, i.e., had an above average value GSI (Fig. 4). No specimens of either sex with an above average GSI were found in August-February.

The percentage of newly recruited juveniles

was highest in June and July, 19% and 12% respectively (Fig. 5). The number slowly decreased from August to October and no new recruits were found in November-May. Average total lengths of the new recruits were 3.91 cm in June, 4.3 cm in July, and 4.1 cm in August.

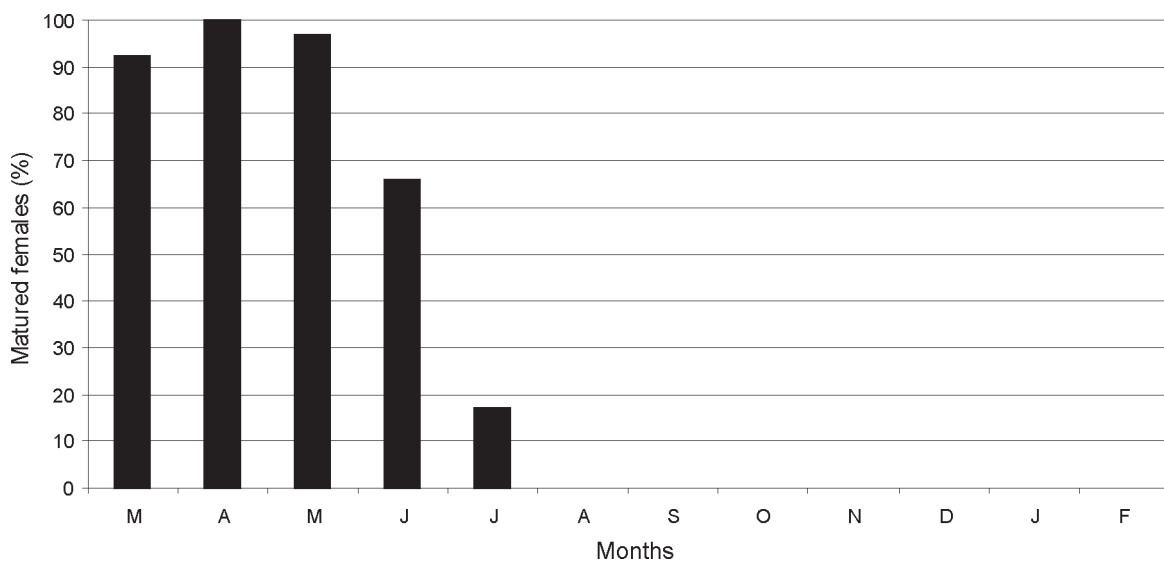


Fig.4. Percentage of mature females in monthly samples of sand smelt

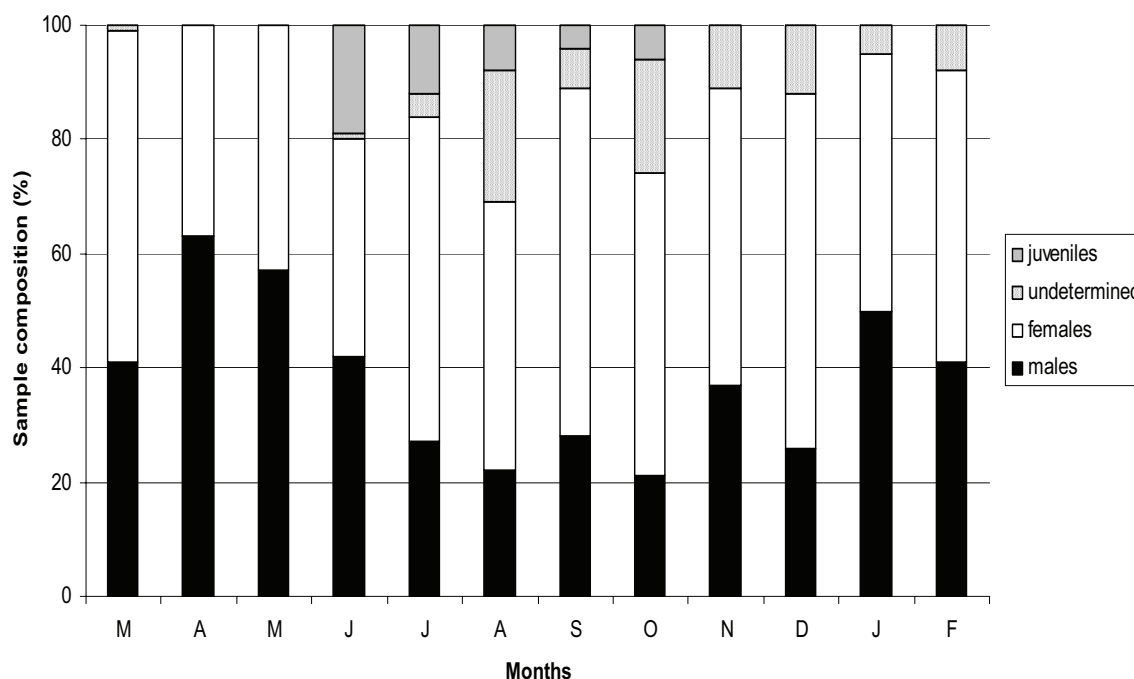


Fig. 5. Percentages of males, females, juveniles, and specimens of undetermined sex, per month

DISCUSSION AND CONCLUSIONS

The smallest mature female in the mouth of Mala Neretva River was 5.2 cm (TL) and 4.3 cm (SL). The smallest female with ripe oocytes in the Mauguio, Mejean, and Perols lagoons, south France, was 3.8 cm SL (TOMASINI *et al.*, 1996). Sexual maturity was attained by females in Aberthaw Lagoon in the Bristol Channel at 3.9 cm SL (CREECH, 1992). Sand smelt from Guadalquivir River in Spain were sexually mature at 4.0 cm SL (FERNANDEZ-DELGADO & HERNANDO, 1982) and sand smelt from Bardawil Lagoon at 3.4 cm SL (GON & BEN-TUVIA, 1983). The smallest mature female in the Suez Canal was no more than 2.7 cm SL (FOUDA, 1994) and sand smelt from Mesolongi and Etolikon lagoons (west Greece) matured at a 3.4 cm TL (LEONARDOS & SINIS, 2000).

The GSI began to rise in March and the highest values were in April. Values remained high in May and decreased in June. The period with high GSI values indicates the extensive reproductive period of sand smelt in the mouth of Mala Neretva River. Similar GSI values

were recorded in sand smelt from the Suez Canal with a maximum of 5.3% for females in February and 4.4% and 4.5% for males in February and March, respectively (FOUDA, 1994). The maximum average GSI in females (8%) was twice as high as in males (4%) in the estuary of the Guadalquivir River (FERNANDEZ-DELGADO *et al.*, 1988). Sand smelt spawned in that area from March to June with a maximum in April. The monthly mean GSI of female sand smelt from Camargue Lagoon in southeastern France rose from January onwards, increased more rapidly from March to May when the GSI reached 13.3%, and dropped from June onwards. In males, the GSI reached a plateau over the same period with a maximum of 9.16% in April (ROSECCHI & CRIVELLI, 1992). The GSI of sand smelt males from brackish lagoons of southern France was lowest in September (0.17%) and peaked in April (10.60%) (TOMASINI & LAUGIER, 2002).

In the Aberthaw Lagoon, development of ovaries starts in March, but the maximum GSI was reached in May for two-year-old fish and in July for one-year-olds (CREECH, 1992).

The annual GSI cycle and values of sand smelt in the mouth of Mala Neretva River are similar to those of the Suez Canal population but significantly lower than those of some French lagoon and other populations. The reasons are difficult to determine, but could be partly explained by the high and unpredictable variation of temperature and salinity in study area

(BARTULOVIĆ, 2003) that leads to disturbances of the sand smelt life cycle. Such disturbances can affect feeding (BARTULOVIĆ *et al.*, 2004a) or cause a high incidence of spinal deformities (TUTMAN *et al.*, 2000). The instability in the ecosystem could significantly influence the reproductive potential of sand smelt in the Neretva River estuary, compared to other researched areas.

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Dozrijevanje i novačenje olige, *Atherina boyeri* Risso 1810 (Pisces: Atherinidae) na ušću Male Neretve (jugoistočni Jadran, Hrvatska)

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SAŽETAK

Prikazane su karakteristike dozrijevanja i novačenja olige, *Atherina boyeri* na ušću Male Neretve, na srednjem dijelu istočne obale Jadrana, Hrvatska u 2001 i 2002. Prosječni gonadosomatski indeks tijekom 12-mjesečnog razdoblja za ženke je iznosio 1,59%, a za mužjake 2,1%. Najveća vrijednost je bila u travnju, za ženke 5,4%, a za mužjake 4,7%. Najmanja zrela ženka je zabilježena pri ukupnoj dužini 5,2 cm, a 50% ženki je bilo zrelo pri ukupnoj dužini 7,75 cm. Nova mlađ se počinje novačiti u lipnju i srpnju, a pojavljuje se i kasnije, ali u manjem broju. Vrijednosti GSI su uglavnom manje nego kod ostalih istraživanih populacija olige. Teško je zaključiti koji je razlog, ali djelomično se može objasniti velikim i nepredvidljivim kolebanjima temperature i slanosti, kod kojih su već opisani različiti poremećaji životnog ciklusa olige na istraživanom području, u ishrani i visokoj učestalosti deformacija kralješnice.

Ključne riječi: oliga, *Atherina boyeri*, dozrijevanje, novačenje, rijeka Mala Neretva