

Growth, mortality and yield of *Atherina boyeri* Risso, 1810 from Lesina lagoon (Adriatic Sea, Italy)

Ermelinda PRATO^{1*}, Asia GRATAGLIANO², Daniela LUMARE³, Febo LUMARE³
Andrea RUSCITO² and Francesca BIANCOLINO¹

¹ *CNR/IRSA (National Research Council/Water Research Institute),
Via Roma 3, 74100 Taranto, Italy*

² *University of Rome "Tor Vergata", Via della Ricerca Scientifica, 1, 00133 Roma*

³ *UNIRIGA (Unità Ricerca Gambericoltura) University of Salento 73100 Lecce, Italy*

**Corresponding author, e-mail: linda.prato@irsa.cnr.it*

*Population structure, growth, age, mortality and exploitation status of *Atherina boyeri*, caught in the period from June 2013 to May 2014 in the Lesina lagoon (Apulia region, southern Adriatic) was studied. Samples were taken each month by using beach seines. The length–weight relationship of all sand smelt specimens was described by the equation $W=0.012*TL^{3.10}$; ($R^2=0.84$). Population parameters including the asymptotic length (L_∞) and growth coefficient (K) were assessed to evaluate the stock status. The recruitment pattern was modeled with a FiSAT routine. The asymptotic length (L_∞) was 111.0 mm, while the growth coefficient (K) was 0.68 year⁻¹. The growth performance index (ϕ') reached 3.92. The total mortality coefficient "Z", the natural mortality coefficient "M" and the fishing mortality coefficient "F" were estimated as 2.24, 1.48 and 0.76 year⁻¹, respectively. Exploitation rate for the population of *A. boyeri* in the Lesina lagoon estimated as 0.34 was resulted still lower than the predicted maximum value of E_{max} 0.59. The probability of capture indicated that L_{50} was of 55.57 mm, indicating that the stock of sand smelt in Lesina lagoon is not being over-fished.*

Key words: *Atherina boyeri*, month variations, age, growth, mortality, exploitation, Lesina lagoon, Adriatic Sea

INTRODUCTION

Coastal lagoons are shallow aquatic environments, typically located between terrestrial and marine ecosystems. They are characterized by a marked variability with wide and rapid changes in environmental parameters, such as salinity, dissolved oxygen, temperature, turbidity, availability of food and the structural characteristics

of the habitat (GORDO & CABRAL, 2001; FRANCO *et al.*, 2006; BASSET *et al.*, 2006). These heterogeneities determine strong environmental variations and, consequently, can cause a selective pressure upon individuals, population and species (MC LUSKY & ELLIOTT, 2004).

The sand smelt *Atherina boyeri* Risso, 1810 is typical inhabits of these aquatic ecosystems; it is an euryhaline and eurythermic teleost fish

species that spends its entire life adapting to over a wide range of salinities and temperatures (ELLIOTT & DEWAILLY, 1995). It is widespread in temperate regions with a broad area ranges, from the western Atlantic coast of Spain to Morocco and Madeira, and is very common in Mediterranean and Black sea. Within such a broad geographical distribution, sand smelt populations are subject to variety of climatic conditions, and often forming different local populations (QUIGNARD & PRAS, 1986).

Aspects of the life history of *A. boyeri* have been reported in previous studies at various locations in the Mediterranean (GON & BENTUVIA, 1983; PALLAORO *et al.*, 2002; BARTULOVIĆ *et al.*, 2004; KOUTRAKIS *et al.*, 2004; POMBO *et al.*, 2005; PATIMAR *et al.*, 2009; MACI & BASSETT, 2010). In the coastal lagoons, the *A. boyeri* plays an important ecological role in structuring food webs, representing a link between different trophic levels (VIZZINI & MAZZOLA, 2002, 2005; CHRISAFI *et al.*, 2007). It is considered as a generalist and opportunistic carnivore with food preferences for small crustaceans, both planktonic and benthonic, and it can constitute a source of food for other fish (BOSCOLO, 1970; FROGLIA & OREL, 1979).

Despite its small size, *A. boyeri* is a target species of fishing and in Italy represents a commercially valuable resource of estuarine systems (MACI & BASSETT, 2010).

Knowledge of the biological characteristics of the fish species are needed to assess the potential of its fishery and management in these habitat (MAGNIFICO, 2007). For this reason, the aim of this study was to provide basic information about some biological parameters of sand smelt, including age and growth, in the Lesina lagoon, an eastern Mediterranean coastal basin.

MATERIALS AND METHODS

Study area, sampling environmental variables

The Lesina Lagoon is situated on the Adriatic coast of Southern Italy (15°45' E, 41°88' N) (Fig.1). Its area amounts to 5136 ha, with an

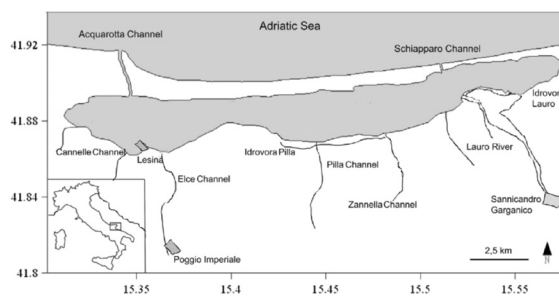


Fig.1. The study area: Lesina Lagoon (Adriatic Sea, southern Italy)

average depth of 0.7 m and a maximum depth of 1.5 m. The lagoon is connected to the sea by two tidal channels (Fig. 1). Specimens of *A. boyeri* were collected monthly by means a manual beach seine (11 m long and 1.30 m high, the central section having a 2 mm mesh and the two lateral sections a 4 mm mesh), from June 2013 to May 2014. The capture happened maintaining a fixed side of the net and sweeping in a circular motion, at 2 knots for 15 min, covering an area of about 150 m².

At all sampling times a set of abiotic variables (temperature, salinity and dissolved oxygen) were directly measured by means of an Idromar IM52 multiparametric probe.

Abundance, Age and Growth Parameters

The fish sampled were measured to the nearest 0.1mm from the anterior tip of the longest jaw to the most posterior part of the caudal fin (TL), and total weight (TW) was taken by an electronic balance of 0.01 g accuracy. Age determination based on otoliths readings and validated by length frequency analysis. Five size classes were performed (classes 0= 15-29 mm; classes 1=30-45 mm; classes 2= 46-60; classes 3= 61-80 mm; classes 4= 81-110 mm).

Length-weight relationship was calculated using $W=aTL^b$ equation (RICKER, 1975), where, W is total weight (g), TL is total length (mm), a is the intercept of the regression line and b is the slope of the equation (exponent "b"). The variation in b values from 3 were tested by the t-test for evaluating growth curve. When the b value in length-weight relationship was equal to or did not show statistically significant deviation from

3, the growth of fish was isometric, whereas when the b value differed significantly from 3 the growth was allometric positive or negative (RICKER, 1975).

Relative condition factor also called Fulton's Condition factor (K) was determined by using equation, $K = (W/L^b) \times 100$ as described by LE CRENS (1951) and FULTON (1911); where K is condition factor, W is total body mass (g), L is body length (mm) and b is the allometry coefficient related to the form of the individual growth, calculated from the length-weight relationship.

The Von Bertalanffy growth function (VBGF) was used by the electronic length-frequency analysis (ELEFAN I) of the FiSAT II program package (GAYANILO *et al.*, 2005) in order to estimate growth parameters: $L_t = L_\infty (1 - e^{-k(t-t_0)})$, where: L_t = mean length at age t , L_∞ = asymptotic length (mm), k = growth coefficient (year⁻¹), t_0 = theoretical age at which the length is zero.

The total mortality (Z) was computed by a linearized length-converted catch curve (PAULY, 1984), based on the following formula:

In $(N_t/\Delta t) = a + bt$, where N is the number of individuals of relative age (t) and Δt is the time needed for the fish to grow through a length class. The absolute value of the curve's slope (b) gives Z .

Natural mortality (M) was estimated using the empirical relationship of PAULY (1980):

$$\log_{10} M = -0.0066 - 0.279 \log_{10} (L_\infty) + 0.6543 \log_{10} (K) + 0.4634 \log_{10} (T)$$

where M is the natural mortality, L_∞ the asymptotic length, K the growth coefficient of the VBGF and T the mean annual habitat water temperature (°C).

The computed value of M and Z Fishing were used to determine the fishing mortality (F) calculated as: $F = Z - M$. The exploitation rate (E) was obtained from $E = F/(F+M)$ (RICKER, 1975).

The probability of capture of each size class was obtained from length-converted catch curve, by backward extrapolation of the catch curve and comparison of the numbers actually sampled with those that were expected to have been sampled. By plotting the cumulative probability of capture against the class interval, it

was obtained a logistic curve from which the size at first capture (LC50%) was taken.

The relative yield-per-recruit (Y/R) and relative biomass-per-recruit (B/R) were determined using the Beverton and Holt model modified by PAULY & SORIANO (1986) to predict the exploitation rate at which the Y/R is highest (E_{max}). In FiSAT, the recruitment patterns were analysed using the maximum likelihood approach of NORSMSEP (Separation of the Normally distributed components of length-frequency samples) to fit the Gaussian distribution on length-frequency data for the year pooled together (PAULY, 1983; MOREAU & CUENDE, 1991; GAYANILO *et al.*, 1995).

Statistical Analysis

One-way ANOVA was applied to assess the differences between growth parameters determined during the period study; when significant differences were found; the mean values were subjected to post-hoc analysis Tukey's test ($p < 0.05$). Relationships between number of individuals and weight of *A. boyeri* and environmental variables (water temperature, dissolved oxygen and salinity) were determined using Pearson's correlation.

RESULTS

Environmental variables

The average values of temperature, salinity and dissolved oxygen with the relative standard deviations are shown in Fig. 2. The lagoon exhibited strong seasonal variations of abiotic parameters (ANOVA; $p < 0.05$). The water temperature followed a seasonal trend, with a minimum value in winter (January and February with values of 9-10°C, respectively) and maximum in summer (June and July with values of 26-27 °C, respectively). Mean monthly values of salinity ranged from 10.5‰ in February to 27‰ in September. Dissolved oxygen attained the maximum value in January (89.6 mg/L) and the minimum value in July (50.1 mg/L), and showed an inverse relationship with temperature

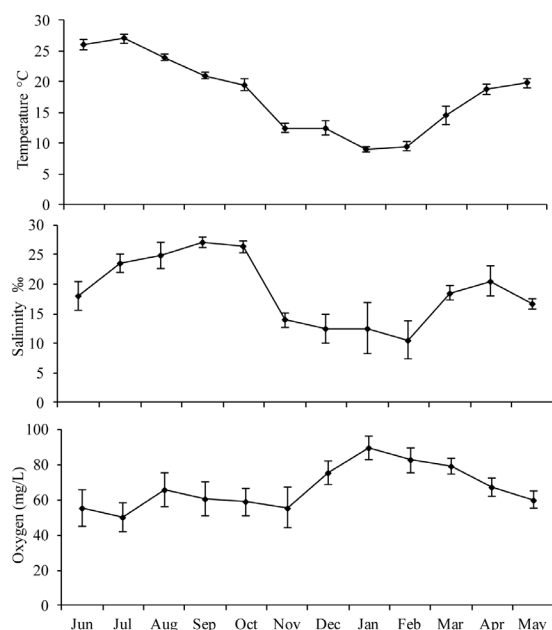


Fig. 2. Temporal variation of water temperature ($^{\circ}\text{C}$), salinity (‰) and dissolved oxygen (mg/L), in the Lesina lagoon (mean \pm S.D.)

($p < 0.05$; $r = -0.74$). Salinity was directly related to temperature ($p < 0.05$; $r = 0.71$) and inversely related to dissolved oxygen ($p < 0.05$; $r = -0.64$).

Abundance, age and growth parameters

A total of 6553 individuals were collected, with a total weight of 8.145 kg; individual number and total weight showed significant differences during the study period (Tukey's test; $p < 0.05$) (Fig. 3). The highest mean number of individuals was found in May and April (1295 and 984 individuals, respectively), while in March and November the lowest (188 and 200 individuals, respectively), while the highest weight of individuals was detected in August and May and the lowest in February and November (Fig. 3).

Relationships between number of individuals and weight of *A. boyeri* with environmental variables indicated that the fish abundance present in lagoon was not influenced by all the three variables measured (Tukey's test, $p > 0.05$), while the weight could be explained by the temperature only (Tukey's test $p < 0.05$).

Of the total individuals caught, a sub-sample of 2005 individuals were measured (Tab.1).

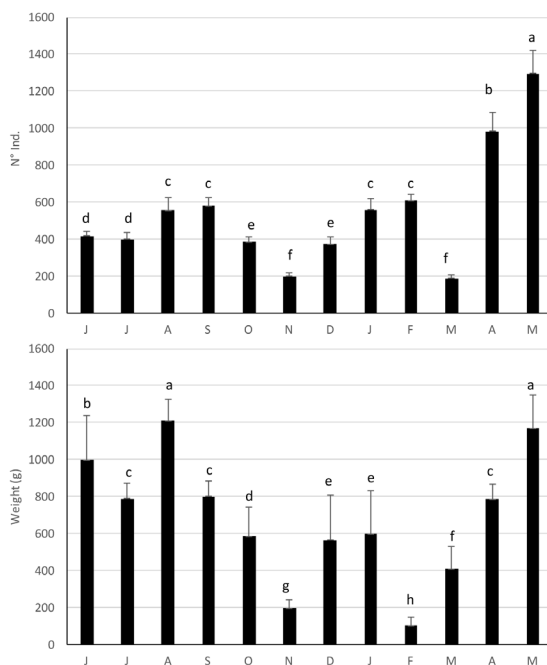


Fig. 3. Temporal distribution of Mean (\pm s.d.) Individuals number and Mean (\pm s.d.) Weight (g) of *Atherina boyeri*, during experimental period. Data with different superscript letters significantly differ ($p < 0.05$)

The length of specimens ranged from 15 mm (February) to 110 mm (August), while the weight ranged from 0.02 g (January and May) to 8.2 g (July) (Tab. 1).

Relationship between total length (TL) and weight for all individuals measured was described by the equation $W = 0.012 \cdot TL^{3.10}$ ($R^2 = 0.84$, $N = 2005$) and displayed a positive allometric growth for the sand smelt population (t test; $p < 0.05$). Monthly values of slope (b) ranged from a minimum of 1.51 in February to a maximum 4.59 in April, showing a significant monthly differences (Tukey's test; $p < 0.05$) (Table1).

The mean condition factor (K) ranged from 14.4 (June) to 0.12 (April). Significant variations of the condition factor showed a decrease in growth rate during winter - spring months (except February with a value of 5.45) and an increase during summer - autumn period (Tukey's test; $p < 0.05$) (Fig. 4).

Otoliths were used for age determination of *A. boyeri* and five age groups (0+ - 4+) were identified in all measured individuals. According to analysis of the otoliths, the length-con-

Table 1. Monthly values of *Atherina boyeri* specimens measured: abundance (N); mean ± standard deviation, minimum and maximum of Total Length (mm) and Wet weight (g); length-weight relationships parameters

	N	Total Length (mm)				Wet weight(g)				$W=aTL^b$		
		Mean	S.D.	Min	Max	Mean	S.D.	Min	Max	a	b	R ²
Total individuals measured	2005	53.8	18.3	15.0	110.0	1.34	1.05	0.02	8.20	0.012	3.10	0.84
June	164	75.3	11.7	38.0	105.0	2.34	1.09	0.40	6.37	0.142	1.82	0.77
July	159	66.8	15.0	39.0	105.0	1.99	1.47	0.32	8.20	0.013	3.02	0.71
August	167	73.3	14.1	39.0	110.0	2.44	01:45	0.29	7.83	0.065	2.20	0.67
September	187	61.5	8.70	39.0	100.0	1.42	0.69	0.35	6.20	0.037	2.55	0.58
October	139	6.11	7.80	42.0	95.0	1.36	0.63	0.50	5.50	0.044	2.45	0.56
November	56	56.9	7.40	43.0	77.0	1.17	0.47	0.60	3.10	0.003	4.02	0.74
December	122	60.2	10.7	34.0	98.4	1.40	0.87	0.38	6.07	0.001	3.33	0.63
January	186	54.0	15.0	25.0	92.0	1.11	0.86	0.02	5.38	0.002	4.08	0.89
February	220	19.2	3.50	15.0	35.0	0.82	0.77	0.04	4.24	0.049	1.51	0.68
March	52	53.0	14.1	30.0	84.0	2.56	0.30	1.98	3.15	0.003	3.86	0.93
April	233	50.1	8.60	37.0	80.5	0.72	0.22	0.36	1.52	0.001	4.59	0.80
May	320	47.4	13.2	30.0	100.0	0.96	0.86	0.02	5.33	0.001	4.43	0.76

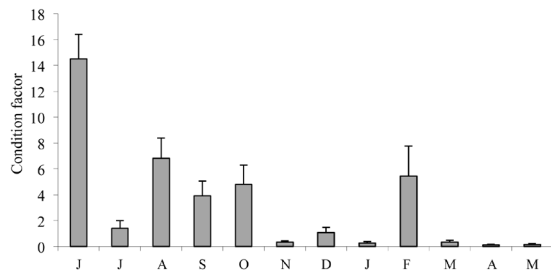


Fig. 4. Monthly Condition factor (K) variation (mean ± S.D.) of *Atherina boyeri* in the Lesina lagoon

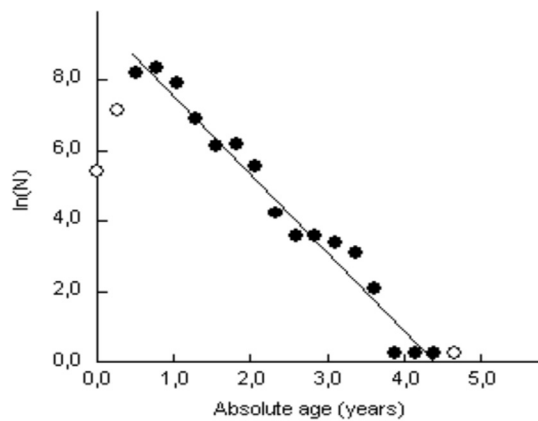


Fig. 5. Length-converted catch curve of the overall *Atherina boyeri* population in the Lesina lagoon

verted catch curve for overall *A. boyeri* population (males and females) showed a longevity of about 4+ (Fig. 5).

The population structure of *A. boyeri* was graphically represented by histograms based on length– frequency distribution. Recruitment of juvenile fish to the sampled population occurred in January until March with a peak of abundance in February (Fig. 6).

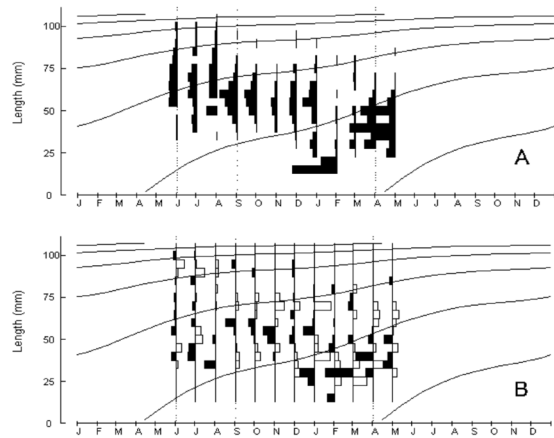


Fig. 6. Overall growth curve of *Atherina boyeri* population superimposed on: A) the normal total length-frequency histograms; B) the restructured; length-frequency histograms

The von Bertalanffy growth parameters were estimated as $L_{\infty}=111.0$ mm, $K=0.68$ year⁻¹ and $t_0=-0.05$ year⁻¹ with a growth performance index $\phi'=3.92$ (Fig. 7).

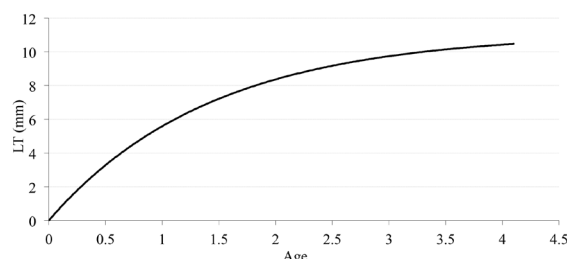


Fig. 7. Estimated von Bertalanffy growth curve during study period

Mortality and exploitation

The total mortality coefficient “Z”, the natural mortality coefficient “M” and the fishing mortality coefficient “F” were estimated as 2.24, 1.48 and 0.76 year⁻¹, respectively. The estimated optimum exploitation rates (relative yield-per-recruit (Y/R) and related coefficient rates (relative biomass-per-recruit (B/R) analysis were reported in Fig. 8. The maximum allowable limit of exploitation level (E_{\max}) that gives the maximum relative Y/R was 0.59, whereas the exploitation level ($E_{0.5}$) which corresponds to 50% of the relative B/R of an unexploited stock was 0.34. The probability of capture as output from FiSAT II were estimated as $L_{50} = 55.6$ mm.

DISCUSSION

The lagoon environment plays an important role in supporting the growth and survival of estuarine species that colonize permanently this transitional ecosystem. Lesina lagoon is a very shallow basin and for this reason its hydrological conditions are strongly influenced by environmental variables, such as seasonal temperature, precipitations trend and by discontinuity in freshwater inputs (ROSELLI *et al.*, 2009). In addition, the tidal regime and the size of the channels limit communication with the open sea. During summer months, the increase of temperature, a low river inflow and low rainfall determine an

increase of salinity. Furthermore, the high temperature favours the microbial decomposition of macroalgal biomass. Indeed, dissolved oxygen reached its lowest values during the summer and autumn months (ROSELLI *et al.*, 2009). Notwithstanding the fluctuations of abiotic factors in the Lesina lagoon, the weight of sand smelt stock was influenced by the temperature only, while the individual number was not influenced by any of the three variables measured. The increase of *A. boyeri*'s weight in summer was probably due to the trophic condition of the lagoon, to inadequate sea-lagoon water exchanges (scarce flow throughout the tidal channels) that brings an accumulation of nutrients from farmland and wastewater discharges from livestock and domestic sources. Consequently, in summer the Lesina lagoon exhibit an increase of both phytoplankton and macrophytobenthos biomass that constitute a source of food for pelagic-benthic organisms (ROSELLI *et al.*, 2009). *A. boyeri* is usually reported as an opportunist or zooplanktonic feeder in marine environment (TRABELSI *et al.*, 1994), but in shallow brackish waters can shift towards a detritus-based food web, including in its diet a wide array of small-sized benthic macroinvertebrates species (CHRISAFI *et al.*, 2007), as confirmed by recent results based on analyses of stable isotope ratios of carbon and nitrogen (VIZZINI & MAZZOLA, 2002, 2005).

The high degree of sand smelt plasticity allows adaptation of life history responses to environmental variables characteristic of coastal and lagoonal habitats; the sand smelt is thus pre-adapted for the exploitation of novel and vacant niches (HENDERSON & BAMBER, 1987). *A. boyeri* in the Lesina lagoon showed a temporal variability in size structure and body condition as observed in other ecosystems. HENDERSON & BAMBER (1987) indicated that the growth and maximum size could reduce along an oceanic-coastal-estuarine-freshwater habitat range.

It has been shown that sand smelt population vary greatly in longevity and maximum size attained. The maximum values of the total length and weight observed in the population of the Lesina lagoon were 110 mm and 8.2 g respectively. Similar results were reported by LEONARDOS (2001) for the same species.

The lifespan of the *A. boyeri* is short and five age groups (0+ - 4+), were observed. Similar age groups were reported for specimens from the English Channel (HENDERSON & BAMBER, 1987), Trichonis lake, Western Greece (LEONARDOS, 2001), Pantana lagoon, Croatia (PALLAORO *et al.*, 2002), Vistonis lake and Porto Lagos lagoon, Northern Greece (KOUTRAKIS *et al.*, 2004) Vaccares lagoon, Southern France (ROSECCHI & CRIVELLI, 1995). However, several authors reported a shorter life cycle (GON & BEN-TUVIA, 1983; LEONARDOS & SINIS, 2000; LEONARDOS, 2001; BARTULOVIĆ *et al.*, 2004; POMBO *et al.*, 2005; PATIMAR *et al.*, 2009; ANDREU-SOLER *et al.*, 2003).

HENDERSON and BAMBER (1987) indicated that sand smelt can adapt its life span, morphology and growth to environmental and geographical locations.

For applied ichthyological studies, 'b' of length-weight relationship is an important key parameter in estimating population growth. Significant monthly variations in slope were observed, in winter and spring, with the slope higher in correspondence of higher concentrations of dissolved oxygen, suggesting that individuals have more metabolic requirements (PETERS, 1986; CLARKE & JOHNSTON, 1999). The values of slope were similar in other European regions that reported a positive allometric growth (PALMER & CULLEY, 1983; CREECH, 1992; LEONARDOS & SINIS, 2000; LEONARDOS, 2001; ANDREU-SOLER *et al.*, 2003; BARTULOVIĆ *et al.*, 2004; KOUTRAKIS *et al.*, 2004; MACI & BASSET, 2010).

In the present study, individuals were not sexed and gonads were not analysed. HENDERSON *et al.* (1988) reported that the post-larvae of *A. boyeri* developed rapidly reaching the length of 24 mm within 2 months. In the Lesina basin small sized individuals were collected in January, February (in high number) and in the catches of May. This probably suggests the occurrence of a spawning season extending from November to April/May. In the summer and early autumn months length-frequency distribution was characterized by individuals ranging from 36 to 110 mm. During these months the individuals body condition increased, probably

due to an increased food availability, that favour larger individuals having a greater ability to feed and increase body mass and fat content. This distribution change in November, when the larger classes disappear and the body condition drop.

In general, the observations regarding the sand smelt condition factor in Lesina lagoon was similar to that reported in other populations (MARFIN 1982, FERNÁNDEZ - DELGADO *et al.*, 1988, ANDREU-SOLER *et al.*, 2003; KOUTRAKIS *et al.*, 2004). The rapid early growth rate through age one was typical of most *Atherinids* (BOSCOLO, 1970; PALMER & CULLEY, 1983; HENDERSON & BAMBER, 1987; FERNANDEZ-DELGADO *et al.*, 1988; CREECH, 1992). Comparison of K and L_{∞} from different lagoon populations in the Mediterranean and the Atlantic coast of Europe showed growth patterns different. In this study, the estimated value of L_{∞} was similar to that Greek Mediterranean lagoons (LEONARDOS & SINIS, 2000; LEONARDOS, 2001), whereas total mortality, natural mortality and of fishing mortality are higher than values reported by KOUTRAKIS *et al.* (2004) in the Northern Greece.

Also the estimated exploitation rate ($E = 0.34$) showed that fishing mortality was lower than natural mortality. The implication is that *A. boyeri* die more due to natural death than human exploitation, therefore, one can infer that the stock of *A. boyeri* is probably submitted to a low fishing pressure. This is based on the assumption that in an optimally exploited stock, natural and fishing mortalities should be equal or $E = F/Z = 0.5$ (GULLAND, 1971). PAULY (1987) and PATTERSON (1992) reported that exploitation rates below 0.4 suggest the tendency toward stock recovery and can be used as a guideline for the sustainable exploitation of small pelagic species.

CONCLUSIONS

Atherina boyeri is important fishery resource, in the Lesina lagoon since it was caught all year round and seem well adapted in this variable environment.

The life traits of this semi-isolated lagoonal population is similar to that of Mediterranean coastal ecosystems. The actual fishery pres-

sure is lower than the exploitation level, which maximizes the relative yield per recruit, a programmed and long term monitoring of the population dynamics and fishery is required in order to confirm the present findings and to maintain the best equilibrium of *A. boyeri* resource in the Lesina lagoon.

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Rast, smrtnost i prinos olige (*Atherina boyeri* Risso, 1810) iz lagune Lesina (Jadransko more, Italija)

Ermelinda PRATO^{1*}, Asia GRATTAGLIANO², Daniela LUMARE³, Febo LUMARE³,
Andrea RUSCITO i Francesca BIANCOLINO¹

*Kontakt adresa, e-pošta: linda.prato@irsa.cnr.it

SAŽETAK

Istraživana je struktura populacije, rast, starost, smrtnost i status eksploatacije olige *Atherina boyeri*, ulovljene u razdoblju od lipnja 2013. do svibnja 2014. u laguni Lesina (regija Apulija, južni Jadran). Uzorci su uzimani svaki mjesec pomoću mreže potegače.

Dužinsko-maseni odnos opisan je jednadžbom $W = 0,012 * TL^{3,10}$; ($R^2 = 0,84$). Utvrđeni su parametri populacije, uključujući asimptotsku duljinu (L_{∞}) i koeficijent rasta (K), kako bi se procijenilo stanje zaliha.

Obrazac novačenja modeliran je FiSAT rutinom. Asimptotska duljina (L_{∞}) iznosila je 111,0 mm, dok je koeficijent rasta (K) iznosio 0,68 godina⁻¹. Indeks učinka rasta (ϕ') dosegno je 3,92. Ukupni koeficijent smrtnosti „Z“, koeficijent prirodne smrtnosti „M“ i koeficijent mortaliteta ribolova „F“ procijenjeni su na 2,24, 1,48 i 0,76 godina⁻¹.

Stopa eksploatacije populacije olige u Lesinskoj laguni procijenjena na 0,34 rezultirala je i dalje nižom od predviđene maksimalne vrijednosti E_{max} 0,59.

Ključne riječi: *Atherina boyeri*, mjesečne varijacije, starost, rast, smrtnost, eksploatacija, laguna Lesina, Jadransko more

