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Ecology and exploitation pattern of a landlocked population of sand smelt, *Atherina boyeri* (Risso 1810), in Trichonis Lake (western Greece)

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Summary

Age, growth, mortality and exploitation pattern of sand smelt, *Atherina boyeri* (Risso 1810), in Trichonis Lake (western Greece) were studied from samples taken from catches of local fishermen. Individuals ranged between 44 and 109.53 mm in total length (TL). Age determinations based on scale readings show that the population has a 4-year life cycle. Sand smelt grows allometrically (b = 3.18) and relatively rapidly, achieving 52.3% of the growth during the first year; thereafter the annual growth rate drops quickly. The von Bertalanffy growth parameters for all individuals are: $L_\infty = 112.40$ mm, k = 0.42 years^{-1} $\kappa\alpha\iota$ $t_o = -0.40$ years. The total mortality rate was $Z = 1.65\ \text{years}^{-1}$ and the natural mortality rate $M = 1.07\ \text{years}^{-1}$. The exploitation rate indicates that the population is rather underexploited (E = 0.35).

Introduction

The sand smelt, *Atherina boveri* (Risso 1810), is a small, short-lived, euryaline teleost fish of faunistic importance in coastal, estuarine and lagoon habitats, salt marshes, and, rarely, inland waters, forming large local populations with a characteristic biology, morphology and life history. It is common in the Mediterranean and adjacent seas, and is also found in the north-east Atlantic from the Azores to the north-west coast of Scotland.

Having arrived through the riverlines and channels of the Acheloos River, the sand smelt is found in the Trichonis and Ozeros lakes of western Greece where it acclimatized and expanded, occupying the ecological niche of pelagic planctophagous fish. This landlocked population is now extremely abundant and supports a valuable commercial purse-seine fishery.

Aspects of the life history of *A. boyeri* have been recorded at various locations in the Mediterranean (Kiener and Spillman, 1969; Boscolo, 1970; Kohler, 1976; Castel et al., 1977; Palmer et al., 1979; Marfin, 1982a, b, c; Gon and Ben-Tuvia, 1983; Palmer and Culley, 1983; Ferrari and Rossi, 1984; Henderson and Bamber, 1986, 1987; Bamber and Henderson, 1988; Fernandez-Delgado et al., 1988; Creech 1992; Trabelsi et al., 1994; Fouda, 1995; Leonardos and Sinis, 1999). Studies concerning the sand smelt from inland waters are scarce. The larval ecology and behaviour of *A. boyeri* as well as 14 other fish species from Trichonis Lake were studied by Economou et al. (1994); the reproductive cycle of sand smelt in Trichonis Lake was also studied by Stoumboudi et al. (1997).

Sand smelt is the most commercialized species of the Trichonis fish fauna and represents the main source of fishing revenues (except eel catches, which have, however, declined over the past decade).

Until 1989, local fishermen used boats with oars or small motors equipped with small gill-nets having a mesh size of 7–8 mm. Beginning in 1989, because of the abundance and high evaluation of sand smelt on the Greek market (approximately US$ 3 per kg), professional trawlers were equipped with larger motors (over 100 HP), and long purse-seines were introduced for lake management. During the past decade the mean commercial catches have been about 500 tonnes per year.

One underlying objective in the management of sand smelt in Trichonis Lake was the development of a strategy that satisfied conservation requirements, but at the same time resulted in a maximization of fishery benefits. The specific goal of this study was to determine the age, growth, mortality and exploitation rate of *A. boyeri* in an attempt to investigate its fishery biology in inland waters.

Study area

Lake Trichonis (38° 15′ N, 21° 30′ E) (Fig. 1) is the largest (96.9 km^2) and deepest (maximum 58 m; average depth 30.5 m) natural lake in Greece. The lake was originally oligotrophic, but is now mesotrophic as a result of human perturbations (Overbeck et al., 1982). A narrow channel allows outflow of surface effluents to the adjacent smaller and shallower Lake Lysimachia which in turn maintains an open connection to the sea through the Acheloos River. Hypolimnion springs and hypsometric divergence between Trichonis Lake and the Achelloos River allows a flow of water from the lake to the river. As of 1961, a dam has prevented the movement of fish and other organisms from Lake Lysimachia to Lake Trichonis.

Materials and methods

Samples were taken randomly from the catches of commercial fishing boats and preserved in neutralized 4% formalin until examination. A 125-HP professional trawler was equipped with a net (150 m length, 30 m depth) with a mesh size of 7 mm in the centre, and 8 mm at the edges. Sampling took place from April 1992 to January 1993. A sample of 503 fish taken in April 1992, 44.0 mm to 109.53 mm TL, was examined for age, growth and mortality. Furthermore, the TL of 866 specimens was measured to study the length frequency distribution of *A. boyeri*, fish being arranged into size groups with intervals of 2 mm (Fig. 2). Total fish length was measured using a digital micrometer with a precision of 0.01 mm. After

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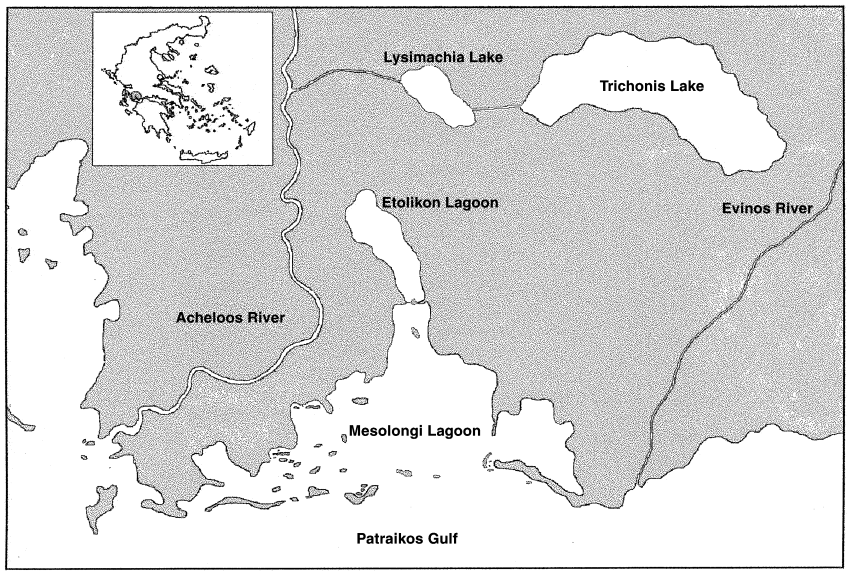

Fig. 1. Map of the Trichonis Lake and adjacent areas

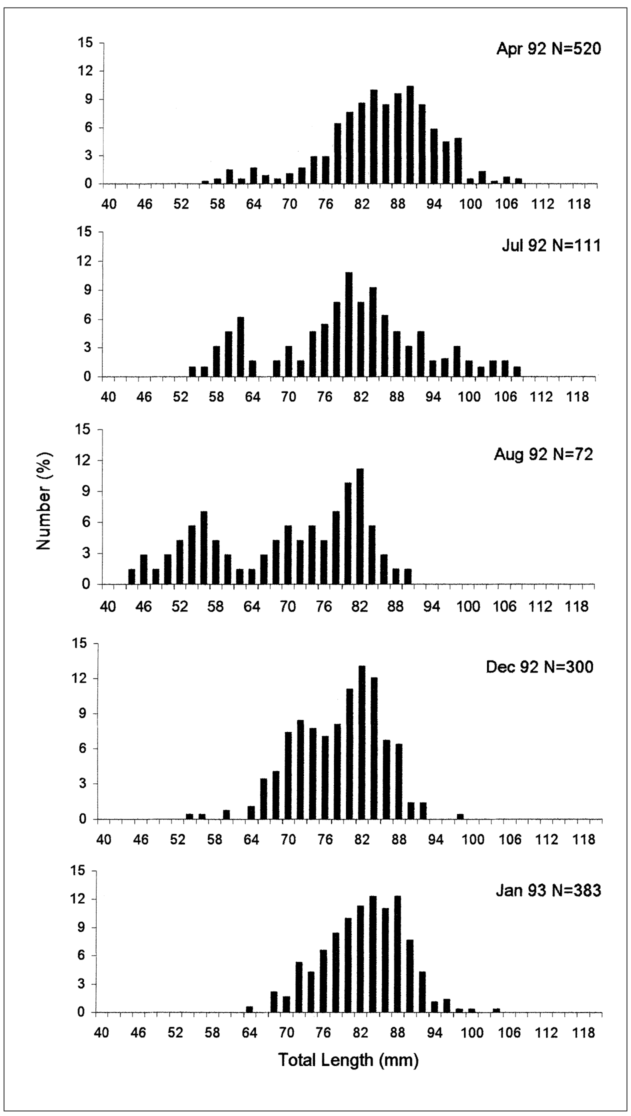

Fig. 2. Length frequency distribution of *Atherina boyeri* from Trichonis Lake

the removal of the intestines and the gonads, body weight was measured using an electronic balance with a precision of 0.1 mg.

Age was determined from scales, which were taken from the left flank along the line of the silver stripe, between the posterior end of the pectoral fin and the anterior end of the dorsal fin. The total radius of the scale and the radius of the annual ring were measured as the smallest distance from the centre of the scale to the distal edge (Marfin, 1982a; Hotos et al., 2000). A stereoscope with transmitted and reflected light was used for the observations.

The back-calculated total lengths were determined using the equation: $TL_n = a + (TL - a)\ Rn/R$ (where TL_n = length of the fish when annulus 'n' was formed, TL = length of the fish when the scale sample was obtained, R_n = radius of annulus 'n'. R = total scale radius, a = intercept on the length axis, of the linear regression relationship between total length and total scale radius) (Bagenal and Tesch, 1978). The von Bertalanffy growth equation was fitted to mean back-calculated lengths at age using the method of Ford-Walford (Everhart and Youngs, 1975).

Total mortality rate was estimated using the cumulated catch curves (Jones and Van Zalinge 1981) $Log_e\ (N_c) = a + Z/k\ Log_e\ (L_\infty - L)$. N_c is the cumulative number of fish of length L and above, L_∞ and k are the parameters of the von Bertalanffy equation, Z/k is the slope of the curve. For the estimation of the total mortality (Z) a catch curve was developed from the length frequency distribution. Natural mortality (M) was estimated using the empirical formula of Pauly (1980):

$$\text{Log}\ (M) = -0.0066 - 0.279\ \text{Log}\ (L_\infty) + 0.6543\ \text{Log}\ (k) + 0.4634\ \text{Log}\ (T)$$

Where L_∞ and k are the parameters derived from the von Bertalanffy equation, T is the mean environmental temperature, which during this study was 17.25 °C. The exploitation rate was estimated using the equation: $E = F/(F + M)$ (Ricker, 1975) where F is the fishing mortality and M is the natural mortality.

Yield per recruit (Y/R) was estimated from the equation:

$$\frac{Y}{R} = F \cdot e^{-M\cdot(t_c - t_r)} W_\infty \sum \frac{U_n \cdot e^{-n\cdot K\cdot(t_1 - t_0)}}{F + M + n \cdot K}$$

Where F is the fishing mortality, M the natural mortality, t_c the mean age at first capture, t_r the age at recruitment, K and t_0 are parameters of the von Bertalanffy growth equation, U_n is a summation parameter $U_0 = 1$, $U_1 = -3$, $U_2 = 3$ and $U_3 = -1$ (Beverton and Holt, 1957). The value W_∞ is the asymptotic weight and was calculated at 11.74 g by using the L_∞ value in the total length–somatic weight relationship. Age at recruitment (t_r) was taken as 0.72 years, corresponding to the age of the smallest fish caught. Parameters of the Y/R equation were estimated using the software programs LFSA (Sparre, 1987).

Results

Age

The scale reading was difficult due to the extension of the annulus formation and the appearance of the annulus ring, which was presented as a dark, thick zone. Furthermore, the long spawning season was the reason for the wide range of lengths in the same year-class (Fig. 2). There was considerable overlap in lengths of fish in adjacent year-classes. Scale readings showed five age classes of which three (0, I and II) were dominant (Table 1). The percentage occurrence of the five age groups (0, I, II, III, and IV) were 36, 30, 21, 12 and 0.2%, respectively. The maximum length observed was 109.53 mm, corresponding to a 4-year-old individual. The relative age frequency distribution of the population was affected by the gear selectivity, which captured specimens larger than 44 mm. The length frequency distribution of all 1386 fish is shown in Fig. 2.

Length–weight relationship

The total length of individuals ranged from 44 to 109.53 mm; the somatic weight was from 0.62 to 10.64 g. The equation of the total length–somatic weight regression, calculated after the log transformation, was: $NW = 3.6\ 10^{-3}\ TL^{3.18}$, $N = 503$, $r^2 = 0.74$. The confidence limits of the slope of the regression were 3.11 and 3.23, showing that the somatic weight grew allometrically with the total length.

Growth

Individuals collected in April 1992 were used to calculate the total length–scale radius relationship. The relationship between total length (TL in mm) and scale radius (R in mm) produced a linear relationship, not associated with origin.

$$TL = 25.96 + 80.91\ R\ (N = 503; r^2 = 0.74)$$

Intercept 'a' from the linear equation of combined sexes was used to back-calculate lengths at age (Table 1). The mean back-calculated TL of each age group was smaller than the observed length of the same age group at the time of catch and greater than the observed TL at the time of catch of the previous age group. Mean back-calculated TL at age indicated rapid growth in the first year of life with the fish attaining almost 52.86% of their maximum adult size during this period and with a sharp decline in growth (24.06%) during the second year. A steady, less rapid decline in mean calculated increments occurred during the third (10.93%) and fourth years (12.14%) (Table 1).

The parameters of the von Bertalanffy growth curves fitted to mean back-calculated TL at age for each sex separately were estimated as $L_\infty = 112.40$ mm, $k = 0.42$ years^{-1} and $t_0 = -0.40$ years, yielding $Lt = 112.40\ [1 - e^{-0.42(t + 0.40)}]$. The theoretical asymptotic TL, 112.40 mm, is realistic as the largest specimen caught during this study had a 109.53-mm TL.

Mortality

The fishing net used was capable of catching specimens with a TL greater than 44 mm (Fig. 2). From the study of the gear selectivity it was found that the LC_{50} was 84.81 mm. This TL corresponds to specimens older than 2 years (Table 1). Total mortality rates were estimated using the cumulated catch curves. The total mortality corresponding to the slope of the curve was found to be $Z = 1.65$ years^{-1} The natural mortality (M) was $M = 1.07$ years^{-1}. The calculation of fishing mortality then gave $F = 0.58$ years^{-1}. The exploitation rate was computed as $E = 0.35$, indicating that the fishing pressure exerted on the *A. boyeri* in Trichonis Lake was rather small.

Yield-per-recruit

The yield-per-recruit as a function of fishing mortality rate was calculated taking values of t_c ranging from 0.72 to 1.3 years, representing values l_c from 46.5 to 63.3 mm. It was observed that with t_c at 0.72 years, the yield increased to a maximum at

Table 1
Back-calculated total lengths (mm) at age of both sexes of *Atherina boyeri* from Trichonis Lake

				Age (years)			
Age (years)	MTLC	95% CI of MTLC	N	1	2	3	4
0 +	48.34	41.88–54.80	181				
1 +	54.18	31.82–76.54	150	49.55			
2 +	77.94	73.20–82.69	104	51.32	73.08		
3 +	84.84	83.31–86.37	60	50.70	70.88	84.91	
4 +	86.12	85.88–86.36	8	50.61	73.76	86.73	95.27
All classes total length (BCTL)				50.36	72.35	84.85	95.27
95% CI of total length				45.08–55.65	66.42–78.46	80.82–89.45	91.15–99.39
% of average annual increments of BCTL				52.86	24.06	10.93	12.14
N			503	321	172	68	8

MTLC, mean total length at capture; N, number of fish; BCTL, Back-calculated total lengths.

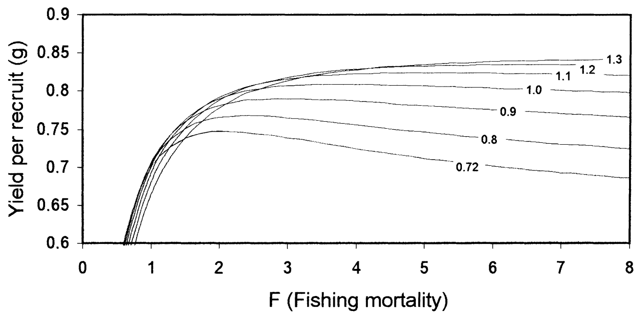

Fig. 3. Yield-per-recruit of *Atherina boyeri* as a function of fishing mortality (F). Numerals indicate the values of age at first capture (t_c) in years

$F = 2.08$ years^{-1} and then declined with a further increase in F (Fig. 3). The yield curves show that with the current value of $F = 0.58$ years^{-1} and $t_c = 0.72$ years, the maximum sustainable yield-per-recruit is about 0.6 g. Also for $F = F_{0.1} = 0.84$ years^{-1} the yield-per-recruit is 0.7 g.

Discussion

One of the life history characteristics of *A. boyeri* is a short life span; the oldest specimen was 4 years of age. The short life cycle exhibited by *A. boyeri* in Trichonis Lake concurs with the expectations of Kiener and Spillman (1969), Palmer and Culley (1983), Henderson and Bamber (1987), Creech (1992), Lorenzo and Pajuelo (1999) and Leonardos and Sinis (1999), who proposed a 3–4-year age structure as typifying populations of Atherinidae species.

The growth rate of *A. boyeri* is particularly high during the first year of life, attaining over half its maximum length (Table 1). After the first year, the annual growth rate drops rapidly. The rapid early growth rate during the first year is typical of most Atherinids (Boscolo, 1970; Turnpenny et al., 1981; Palmer and Culley, 1983; Henderson and Bamber, 1987; Fernandez-Delgado et al., 1988; Creech, 1992). The estimated L_∞ (112.40 mm) was in close agreement with the maximum TL recorded ($L_{max} = 109.53$ mm) and within the range of previous investigations (Table 2). Also Economou et al. (1994) reported that *A. boyeri* live up to 3 years (exceptionally to 4 years), reaching a TL of 135 mm.

According to Henderson and Bamber (1987), a life history trend is apparent in *A. boyeri* along an oceanic–coastal–estuarine–freshwater habitat axis where the growth, such as the maximum length, is reduced. In the present study and in terms of *A. boyeri* in Mesolongi and Etolikon lagoons (Leonardos and Sinis, 1999), no differences were found between lagoon and lake in relation to the parameters and the rate of growth. It seems that the high degree of phenotypic plasticity of *A. boyeri* allows for an adaptation in response to variable habitats. The sand smelt migrate from adjacent coastal areas via the Acheloos River into the Trichonis Lake; because pelagic planktivorous fish and pelagic predators are absent, there is no other freshwater fish competition. Bamber and Henderson (1988) reported that in countries where true freshwater fishes are scarce or absent, species of sand smelts have become permanent residents in freshwater bodies. This fact, in combination with the high degree of adaptability, early maturity and rapid growth rates of sand smelt, allows their colonization of the vacant niche of the lake, permitting them to become an extremely abundant landlocked population. According to Henderson and Bamber (1987), the fish is pre-adapted for the exploitation of novel or vacant niches.

From the study of gear selectivity it was found that the LC_{50} is 84.81 mm; this length corresponds to 2-year-old specimens. Early sexual maturation, even within the first year-class (Gon and Ben-Tuvia, 1983; Henderson and Bamber, 1987; Fernandez-Delgado et al., 1988; Creech, 1992; Stoumboudi et al., 1997; Leonardos and Sinis, 1999), and the fact that gear capture specimens only above the 2-year size, allow a large portion of the population to reproduce. The exploitation rate shows an unexploited population ($E = 0.35$). One of the characteristics of the biological strategy of *A. boyeri* is a short life span; high mortality rates of the mature fish, especially after the reproduction period, are expected. Patterson (1992) reported that an exploitation rate of about $E = 0.4$ is safe for the stock and may be used as a guideline for the appropriate exploitation of small pelagic species. Indications from the exploitation strategy show that the stocks of Atherina in Trichonis Lake are not in decline; moreover, the catch of sand smelt during the year September 1998–September 1999 was 530 tonnes (unpublished data). Fishing for sand smelt frequently tapers off, due to its plenitude and low market value.

Table 2
Age structure, parameters of the length–weight relationship (a, b) and growth (L_∞, k, t_o) of the *Atherina boyeri* in this study and in studies by other authors

Authors	Study area	Max. age (years)	N	b	L_∞ (mm)	K (years^{-1})	t_o (years)
Kohler (1976)[a]	Prevost Lagoon, France		1400	3.2			
Castel et al. (1977)[a]	Arcachon Bay, France	2	3409	2.89–3.21			
Palmer and Culley (1983)[b]	Oldbury-upon-Severn, England	3	67	3.36			
Gon and Ben-Tuvia (1983)[b]	Bardawil Lagoon, Sinai	1–2			42	2.93	
Henderson and Bamber (1987)[b]	English Channel populations	4	138	0.7			
Fernandez-Delgado et al. (1988)[c]	Guadalquivir River, Spain	2	2510	2.98–3.15			
Creech (1992)[b]	Aberthaw Lagoon, S. Wales	2	329	3.27	92		
Stoumboudi et al. (1997)[a]	Trichonis Lake, W. Greece		2543	3.21			
Leonardos and Sinis (1999)[a]	Mesolongi and Etolikon lagoons, W. Greece	3	4269	3.15	115.79	0.24	−1.27
Present study	Trichonis Lake, W. Greece	4	503	3.18	112.4	0.42	−0.4

[a] Using Total length, [b]using Standard length, [c]using Fork length.

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References

Bagenal, T.; Tesch, F., 1978: Age and growth. In: Methods for Assessment of Fish Production in Fresh Waters. Ed.: T. B. Bagenal, IBP Handbook No 3. Blackwell Scientific Publications, Oxford, pp. 101–136.

Bamber, R.; Henderson, P. A., 1988: Pre-adaptive plasticity in atherinids and the estuarine seat of the teleost evolution. J. Fish Biol. **33,** 17–23.

Beverton, R. J. H.; Holt, S. J., 1957: On the dynamics of exploited fish populations. Fish Invest. Ser. II, Mar. fish., G. B. Minist. Agric. Fish. Food 19.

Boscolo, I., 1970: Observazoni sulla biologia e sulla pesca dell, *Atherina boyeri* Risso, 1810 (Osteichthyes Atherinidae) vivente nelle acque dell′ alto Adriatico. Boll. Pesca Piscic. Idrobiol. **25,** 61–79.

Castel, J.; Cassifour, P.; Labourg, P.-J., 1977: Croissance et modifications du régime alimentaire d'un teleosteen Mugiliforme: *Atherina boyeri* Risso, 1810. Dans les étangs saumatres du basin d'Arcachon. Vie Milieu, Series (3-a) **27,** 385–410.

Creech, S., 1992: A study of the population biology of *Atherina boyeri* Risso, 1810 in Aberthaw Lagoon, on the Bristol Channel, in South Wales. J. Fish Biol. **41,** 277–286.

Economou, A. N.; Daoulas, C. h.; Psarras, Th.; Barberi-Tseliki, R., 1994: Freshwater larval fish from Lake Trichonis (Greece). J. Fish Biol. **45,** 17–35.

Everhart, W. H.; Youngs, W. D., 1975: Principles of Fishery Science. Cornell University Press, Ithaca, New York.

Fernandez-Delgado, C.; Hernando, J. A.; Herrera, M.; Bellido, M., 1988: Life history patterns of the sand smelt *Atherina boyeri* Risso, 1810 in the estuary of the Guadalquivir River, Spain. Estuarine Coastal Shelf Sci. **27,** 697–706.

Ferrari, I.; Rossi, R., 1984: Regime alimentare di *Atherina boyeri* in una laguna del delta del Po. Nova Thalassia **6,** 275–280.

Fouda, M. M., 1995: Life history strategies of four small-size fishes in the Suez Canal. Egypt. J. Fish Biol. **46,** 687–702.

Gon, O.; Ben-Tuvia, A., 1983: The biology of Boyer's sand smelt, *Atherina boyeri* Risso, in the Bardawil Lagoon on the Mediterranean coast of Sinai. J. Fish Biol. **22,** 537–547.

Henderson, P. A.; Bamber, R., 1986: Sand smelt in the fleet. Por. Newslett. **3,** 149–151.

Henderson, P. A.; Bamber, R., 1987: On the reproductive biology of the sand smelt *Atherina boyeri* Risso (Pisces: atherinidae) and its evolutionary potential. Biol. J. Linnean Soc. **32,** 395–415.

Hotos, G.; Avramidou, D.; Ondrias, I., 2000: Reproduction biology of *Lisa aurata* (Risso, 1810), (Pisces: Mugilidae) in the lagoon of Klisova (Messolonghi, W. Greece). Fish. Res. **47,** 57–67.

Jones, R.; Van Zalinge, N. P., 1981: Estimates of mortality rate and population size for shrimp in Kuwait. Kuwait Bull. Mar. Sci. **2,** 273–288.

Kiener, A.; Spillman, C. J., 1969: Contribution a l′ étude systematique et ecologique des atherines des côtes françaises. Memoires du Museum d′ Histoire Naturelle, Series A. Zoology **40,** 33–74.

Kohler, A., 1976: Observations biologiques et biometriques sur *Atherina boyeri* Risso dans l'étang du Prevost a Palavas (Herault). Vie Milieu. **26** (1-A)**,** 157–174.

Leonardos, I. D.; Sinis, A., 1999: Age, growth and mortality of *Atherina boyeri* Risso, 1810 (Pisces: atherinidae) in the Mesolongi and Etolikon Lagoons (W. Greece). Fish. Res. in press.

Lorenzo, J.; Pajuelo, J., 1999: Age and growth of the sand smelt *Atherina (Hespetia) presbyter* Cuvier, 1829 in the Canary Islands (Central-east Atlantic). Fish. Res. **41,** 177–182.

Marfin, J. P., 1982a: Croissance de l'Atherine *Atherina boyeri* Risso, 1810 dans trois milieux saumatres du Roussillon. Bull. Inst. Natl. Scient. Tech. Oceanogr. Pêche Salambo **9,** 89–109.

Marfin, J. P., 1982b: Alimentation et condition de l'Atherine *Atherina boyeri* Risso, 1810 durant un cycle annuel. J. Rech. Oceanogr. **7,** 12–40.

Marfin, J. P., 1982c: Les problemes au polymorphisme de l'espèce *Atherina boyeri* Risso, 1810. Cybium **6,** 19–26.

Overbeck, J.; Anagnostidis, K.; Economou-Amili, A., 1982: A limnological survey of three Greek lakes: Trichonis, Lyssimachia and Amvrakia. Arch. Hydrobiol. **95,** 365–394.

Palmer, C.; Culley, M., 1983: Aspects of the biology of the sandsmelt *Atherina boyeri* Risso, 1810 (Teleostei: atherinidae) at Oldbury-upon-Severn, Gloucestershire, England. Estuarine, Coastal Shelf Sci. **16,** 163–172.

Palmer, C. J.; Culley, B. M.; Claridge, N. P., 1979: A further occurrence of *Atherina boyeri* Risso 1810 in north-eastern Atlantic waters. Environ. Biol. Fish. **4,** 71–75.

Patterson, K., 1992: Fisheries for small pelagic species: an empirical approach to management targets. Rev. Fish Biol. Fish. **2,** 321–338.

Pauly, D., 1980: On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. Explor. Mer **39,** 175–192.

Ricker, W. E., 1975: Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. **191,** 235–264.

Sparre, P., 1987: Computer programs for fish stock assessment, length-based fish stock assessment for Apple II computers. FAO Fish. Technical Paper 101 (Suppl. 2).

Stoumboudi, M. Th.; Psaras, Th.; Barbieri-Tseliki, R., 1997: Reproductive cycles of atherina (*Atherina boyeri,* Risso, 1810) from Trichonis Lake (Greece). Proc. 5th Hel. Symp. Oceanogr. Fish. **2,** 257–260.

Trabelsi, M.; Quignard, J.-P.; Kartas, F., 1994: *Atherina boyeri*: Premiere mention en Méditerranée de deux populations marines sympathiques. Cybium **18,** 457–459.

Turnpenny, A. W. H.; Bamber, R. N.; Henderson, P. A., 1981: Biology of the sand-smelt (*Atherina presbyter* Valenciennes) around Fawley power station. J. Fish Biol. **18,** 417–427.

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