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Life-history Traits for Eight Fish Species of the Largest Greek Lake (Lake Trichonis)

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Abstract: The knowledge of the life-history traits of commercial and data-deficient fish species is essential for assessing, among others, their status, as well as for the formulation of conservation measures and the implementation of sustainable managerial decisions. In the present study, growth parameters were estimated for eight fish species of the Lake Trichonis (Greece): *Atherina boyeri*, *Cobitis trichonica*, *Leucos panosi*, *Luciobarbus albanicus*, *Rhodeus meridionalis*, *Salaria economidisi*, *Scardinius acarnanicus* and *Tropidophoxinellus hellenicus.* The mortality and exploitation status were estimated for the five most exploited ones (*A. boyeri*, *L. panosi*, *L. albanicus*, *S. acarnanicus* and *T. hellenicus*). For four of the above-mentioned species (*C. trichonica*, *R. meridionalis*, *S. economidisi* and *T. hellenicus*), life history data were provided for the first time. *A. boyeri* (a commercially important and the most exploited species in the lake) and *T. hellenicus* (a discarded species) exhibited the highest values of fishing mortality, followed in descending order by *L. albanicus*, *L. panosi* and *S. acarnanicus*. The information produced in the present study can be incorporated in ecosystem-based models aiming at the establishment of management and conservation measures at both species level and ecosystem level.

Key words: von-Bertalanffy growth function, ELEFAN, Length-frequency

Introduction

The estimation of life-history traits (i.e., growth parameters, fisheries and natural mortalities as well as exploitation rate) of fish species can be used, among others, to evaluate whether the fish resources are sustainably exploited. Reliable estimation of these traits is also essential for the development of ecosystem models that can be subsequently used for the establishment of conservation and management measures (Petriki et al. 2021).

The aim of the present study is the estimation of the life-history traits of eight fish species inhabiting the largest lake in Greek territory, Lake Trichonis: *Atherina boyeri*, *Cobitis trichonica*, *Leucos panosi*, *Luciobarbus albanicus*, *Rhodeus meridionalis*, *Salaria economidisi*, *Scardinius acarnanicus* and *Tropidophoxinellus hellenicus*. Prior to this

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study, life history data were existed for four of the species under study, based on surveys conducted in Trichonis or other Greek lakes during the last 30 years. These were *A. boyeri* (Leonardos & Sinis 2000, Leonardos 2001, Koutrakis et al. 2004), *R. panosi* (Daoulas 1984, Neophitou & Theochari 1989, Leonardos et al. 2005), *S. acarnanicus* (Iliadou 1981, Leonardos 2004), *L. albanicus* (Daoulas & Economidis 1989, Bobori et al. 2006). However, no life history data existed worldwide for *C. trichonica*, *R. meridionalis*, *S. economidisi* and *T. hellenicus*.

With the exception of *A. boyeri*, all the aforementioned species are endemic to Western Greece or to the Acheloos drainage (Bobori & Economidis 2006), Moreover, *C. trichonica*, *L. panosi* and *S. economidisi* have a threatened Red List status. Thus, their protection should be set as a priority especially under the pressures of (e.g., Arthington et al. 2016, Freyhof & Brooks 2011, Markovic et al. 2017, Moutopoulos et al. 2023): (a) overfishing, (b) habitat and water degradation, (c) species invasion from unintentional introductions, (d) climate change and (e) inter-specific competition, or (f) their synergistic effect. The present study deals with the estimation of life history traits of eight fish species in the lake Trichonis, which would fulfil the gap of knowledge regarding their biology and ecology, especially for certain data-deficient ones.

Materials and Methods

Study area

Lake Trichonis, located in the prefecture of Aitoloakarnania in the western part of Greece (38°33´0.59´´ N, 21°33´8.99´´ E), is the largest natural lake of the country with a surface area of 98.6 km^2 and a catchment area of 421 km^2. It is a deep (maximum depth = 57 m, mean depth = 29 m), warm and monomictic lake (it exhibits a long period of thermal stratification during the hottest months to autumn), with oligotrophic to mesotrophic characteristics (Kehayias & Doulka 2014). It receives both surface and groundwater inflows maintaining a positive water balance. The lake occasionally outflows to Lake Lysimachia through a narrow surface channel (2.8 km long) for preventing floods.

Fisheries exploitation is conducted with artisanal fishing gears, mainly set nets (i.e., trammel and gill nets) and encircled nets (used only by three fishing vessels at areas with depth greater than 35 m). The latter are exclusively used for catching *A. boyeri* (Petriki et al. 2021), the most commercially valuable species of the lake. There is small market demand of the other fish species in the lake such as, *L. panosi*, *L. albanicus* and *S. acarnanicus* (which are caught mainly as by-catch). However, the rest of the species are either not caught due to the selectivity properties of the fishing gear used (i.e., *C. trichonica*, *R. meridionalis* and *S. economidisi*) or caught in high numbers and subsequently discarded due to their negligible commercial value (i.e., *T. hellenicus*) (Petriki et al. 2021). The above result in a low overall fisheries pressure on the fish stocks (Petriki et al. 2021).

Sampling

A random stratified seasonal (March, May, August, November) fish survey was conducted in 2019, following the European standards (EN14757) for ichthyofauna monitoring in lake water bodies (Cen 2005). All nets were set before sunset and hauled after dawn, ensuring a stable soak time of approximate 12 h (details in Petriki et al. 2021).

Monthly samples of *A. boyeri* were also obtained from commercial catches during 2019–2020. These were 10 monthly samples from May 2019 to February 2020) (for details, see Douligeri et al. 2021). We used an encircled net with maximum length up to 150 m, height up to 30 m and minimum mesh size of 6 mm complemented with the use of light (up to three electric lamps with maximum light intensity of 1500 lm) at depths greater than 35 m. All individuals were identified at the species level, measured for total length (TL) to the nearest 1 mm and weighted to the nearest 0.01 g.

Growth parameters

Length frequency data for the eight fish species under study were constructed. For the estimation of the life history traits for *A. boyeri* samples obtained both from Nordic type gill nets and encircled net were combined. The Kolmogorov-Smirnov analysis (K-S test) (Zar 2010) was used to compare the distributions between the two different gears. Von Bertalanffy growth rate (K) and the asymptotic length (L_∞) were estimated by modal progression analysis, using the FISAT II program (Gayanilo et al. 1996) and the ELEFAN I method (Pauly 1984). For the modal progression analyses, length classes were defined per 5 mm, for all of the fish species, except for *L. albanicus* and *S. acarnanicus*, in which classes of 10 mm were used. Goodness index Rn was used as a criterion to identify the (seasonally oscillating) growth curve that "best" fitted a set of length-frequency data (Pauly 1984). To improve the estimation of fish life span, a default value for t_0 was estimated from L_∞ and K based on the empiri-

Table 1. Estimated life history parameters of eight fish species from Lake Trichonis, 2019-2020. Explanations of abbreviations are provided in text. * Indicates the non-exploited species. n: number of specimens, TL: Total length, Rn: Goodness index, L_∞: asymptotic length, K: growth coefficient of the VBGF, φ: growth performance index, M: natural mortality, E: rate of exploitation, F: fishing mortality. In all of the cases the temperature was considered equal to 17.3 ºC.

Species	n	TL range (mm)	Average (SD)	Rn	L_∞ (mm)	K (years^{-1})	t_o	M	Z Length converted	Z-95%	Z+95%	E	F	φ'
Atherina boyeri	6773	41-125	78.0 (12.0)	0.548	127.00	0.83	-0.130	0.844	3.450	3.170	3.730	0.755	2.606	4.127
*Cobitis trichonica**	39	53-100	78.0 (14.0)	0.871	104.50	0.44	-0.265	1.118						3.680
Leucos panosi	1358	61-289	118.0 (24.0)	0.334	296.20	0.12	-0.765	0.357	0.700	0.600	0.800	0.490	0.343	4.022
Luciobarbus albanicus	253	56-474	146.0 (80.0)	0.311	502.80	0.21	-0.370	0.234	0.950	0.610	1.300	0.754	0.716	4725
*Rhodeus meridionalis**	63	37-75	59.0 (9.0)	0.818	81.65	0.86	-0.141	1.857						3.560
*Salaria economidisi**	34	38-70	55.0 (8.0)	0.885	82.20	0.59	-0.210	0.738						3.550
Scardinius acarnanicus	466	62-345	132.0 (51.0)	0.295	397.00	0.22	-0.376	0.256	0.890	0.710	1.060	0.712	0.634	4.540
Tropidophoxinellus hellenicus	6772	40-115	69.0 (12.0)	0.266	125.10	0.68	-0.160	0.744	3.840	3.470	4.200	0.806	3.096	3.600

cal equation of Pauly (1979): $Log(-t_0) = -0.3922 - 0.2752 * LogL_\infty - 1.038 * LogK$.

The above estimated values were subsequently used for the calculation of the instantaneous annual mortality rate (Total mortality rate, Z) (Pauly 1983) by the length-converted catch curve for the five most exploited species. Total mortality rate (Z) was also estimated, using the Beverton and Holt model (Beverton & Holt 1956): $Z= K (L_\infty – L_{mean}) / (L_{mean} – L')$, where, L_∞ is the asymptotic length, K is the curvature parameter of the VBGF, L_{mean} is the mean length and L' is the lower limit of the smallest length class included in the computation. The growth performance index (φ´) was calculated with the following equation (Pauly & Munro 1984): $φ´ = LogK + 2 * LogL_\infty$.

The natural mortality (M) was calculated by Pauly's empirical equation using the growth parameters L_∞ and k of each species previously estimated (Pauly 1984): $Log(M) = -0.0066 – 0.279 * Log(L_\infty) + 0.6543 * Log(K) + 0.4634 * Log(T)$, where T is the mean annual temperature of the lake based on our estimates (T = 17.3 ºC). For the calculation of the fishing mortality (F), natural mortality (M) was subtracted from total mortality (Z). The rate of exploitation (E) was calculated from the estimated values F and Z for the exploited fish species only, using the following formula (Gulland 1983): E = F/Z. For a rationally exploited stock, the fishing mortality (F) must be equal to the natural mortality and E equal to 0.5 (Sparre et al. 1989).

Results

Descriptive statistics, estimates of growth and fisheries' mortality parameters calculated by ELEFAN I method for all studied species are presented in Table 1.

Length distribution shown that (Fig. 1) *C. trichonica* peaked to 80-90 mm length, and *S. economidisi*, *R. meridionalis* and *T. hellenicus* peaked to 55 m, 60 mm and 65 mm, respectively. *L. albanicus* peaked to 70-80 mm and *L. panosi* and *S. acarnanicus* to 90-110 mm. Length distributions for *A. boyeri* exhibited significantly (K-S, $P<0.05$) difference between gears with the length classes peaked to 55-60 mm and 70-80 mm for Nordic nets and encircled gear, respectively, indicating that encircled gear caught larger individuals. The estimated L_∞ values ranged from 81.65 mm for *R. meridionalis* to 502.80 mm for *L. albanicus*. Rate K values ranged from 0.12 years^{-1} for *L. panosi*, to 0.86 years^{-1} for *R. meridionalis*. Growth performance index (φ´) values ranged from 3.55 for *S. economidisi*, to 4.72 for *L. albanicus*. The species that are mainly affected by the local fishery were the discarded species *T. hellenicus* and the commercially

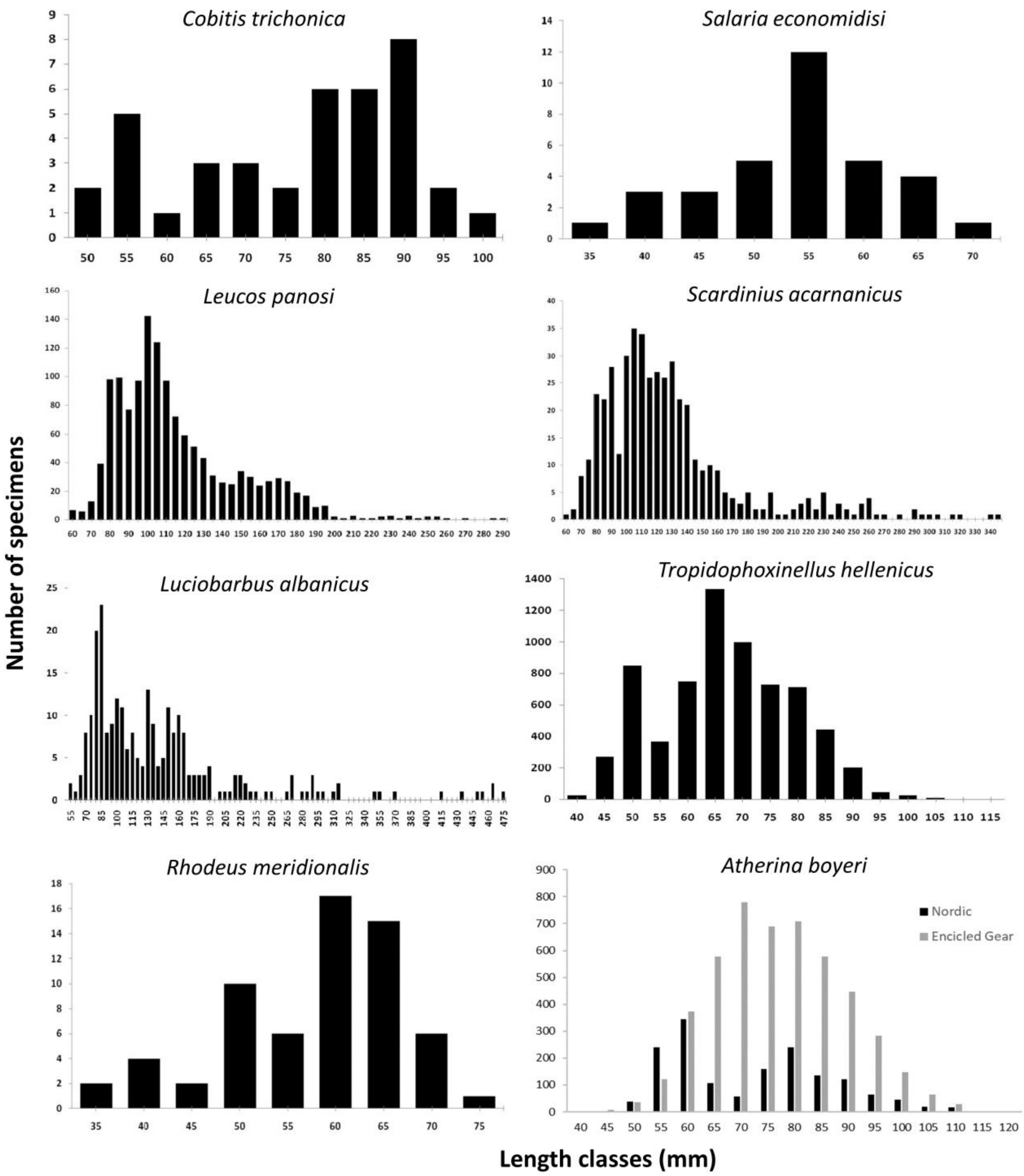

Fig. 1. Number of specimens per length class, for the eight studied species caught in Lake Trichonis during 2019–2020.

important *A. boyeri*, which exhibited the highest values of fishing mortality followed by *L. albanicus*, *S. acarnanicus and L. panosi*. The Z curves produced from the length converted catch curve method are given in Figure 2. The exploitation rate E for the fishery-exploited species ranged from 0.490 for *L. panosi*, to 0.806 for *T. hellenicus* (Table 1).

Discussion

The present study deals with the estimation of life history traits of eight fish species in the lake Trichonis in order to fill the gap of knowledge regarding the biology and ecology of data-deficient species. The growth parameters estimated in this study are in accordance with those reported from other studies in Greek and international lakes (Table 2). The estimated L∞ values were in accordance with the species' maximum reported lengths (Froese & Pauly 2021). The L_∞ values for *A. boyeri* estimated in this study were higher than those estimated 20 years ago for the same area while the K value was lower (Leonardos 2001). The estimated L_∞ and K values for the same species were lower and higher, respectively, to those reported for Lake Iznik in Turkey (Özeren 2009). Such differences could be attributed to the fishing gear used. It is noteworthy that Leonardos (2001) used a trawl net with mesh size 7 mm, Özeren (2009) a net of mesh

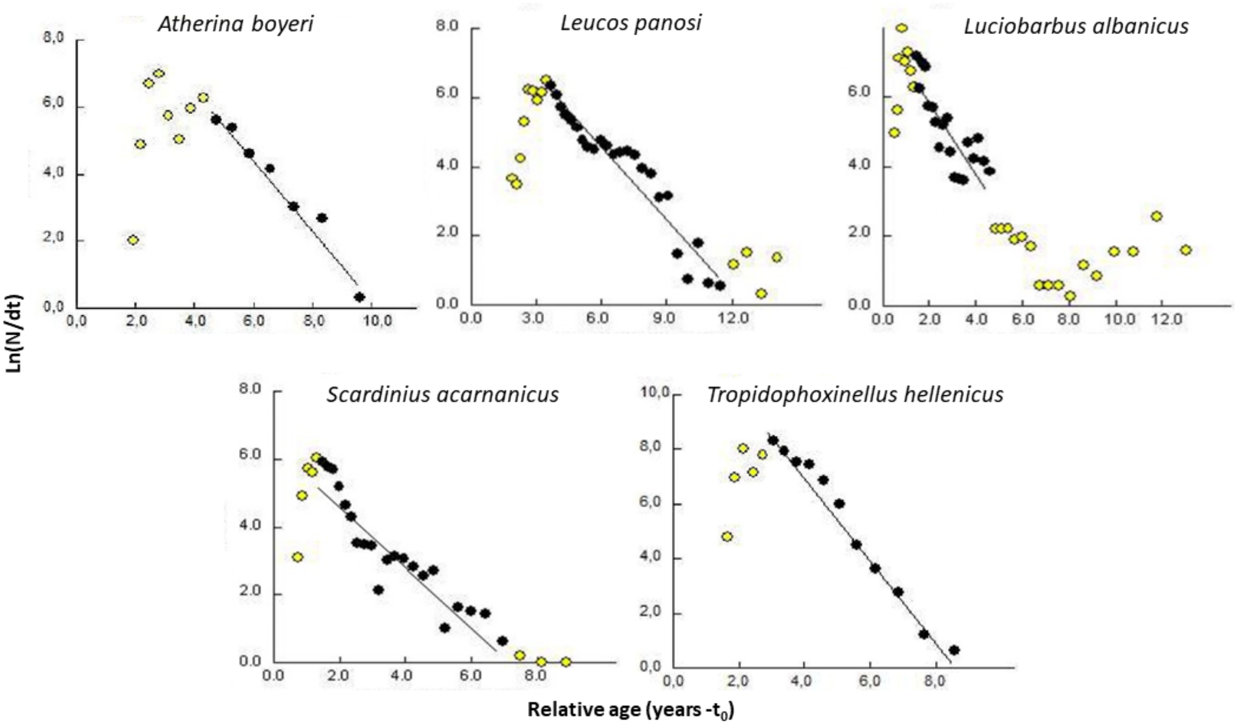

Fig. 2. Total mortality Z curves ((ln(N/dt) versus relative age)), using length converted catch curve method, for five of the studied species caught in Lake Trichonis during 2019–2020. Black points highlighted the data used for the estimation of total mortality values.

size of 5 mm and in the present study samples were caught using an encircled net of 6 mm mesh size. The values of L_∞ for *A. boyeri* were similar with those estimated from studies conducted in Lake Trichonis and in the adjacent Lake Lysimachia almost two (Leonardos 2004) and four (Iliadou 1981) decades ago, while K value estimated higher than those estimated in the same studies. For *L. albanicus* the values of L_∞ and K estimated in the present study were higher compared to those estimated by Daoulas & Economidis (1989) in the adjacent Kremasta Reservoir and similar to the values estimated in Tavropos Reservoir (located in Central Greece) during 2005–2006 (Bobori et al. 2006). The growth parameters estimated for *L. panosi* in Lake Trichonis during 1991–1992 were close to these estimated in the present study, whereas Neophitou & Theochari (1989) estimated lower L_∞ and higher K values from samples caught in northern Greece (Lake Pamvotis) during 1983–1984.

Differences in growth patterns exhibited among different populations may be attributed to differences in their genetic structure, environmental conditions, food availability and diseases (Wotton 1998). In addition, comparisons of the natural mortality estimates are controversial, because they may be affected by the method used, the study area and the ecosystem's food web structure (Sun et al. 2003). For instance, in Lake Trichonis, the natural mortality for *A. boyeri* incorporates also the inter-specific prey-predation interaction imposed to the species by the predatory behaviour of *S. acarnanicus* (Tsounis & Kehayias 2021b, Petriki et al. 2021).

Our estimates on life history traits can be considered to be mean annual values for the studied species, because almost equal fish samples were obtained throughout seasons. For *A. boyeri* the use of two different gears increased the representation of the whole population in our estimates and reduced the bias produced by the size-selective properties of the gears used. The fishing mortality values for *A. boyeri* estimated from the present study was higher than those estimated from studies conducted in mid-1990s (Leonardos & Sinis 2000, Leonardos 2001) (3.45 vs 1.65, respectively) revealing the highest exploitation rate of the species nowadays. Exploitation rate greater than 0.5 is an indication of overfishing (Pauly 1984); according to Patterson (1992), the maximum E level for the pelagic fish stocks such as *A. boyeri* and *T. hellenicus* should be maintained at 0.4 for their optimal exploitation. In the present study, for all the exploited species, apart for *L. panosi* (E = 0.490), the estimated E values were greater than the overexploited limit (= 0.50).

The mean production of *A. boyeri* using encircled nets reached approximately 500 tons per year, almost two decades ago and still today the species'

Table 2. Literature review of the biological parameters estimated for the studied species. Explanations of abbreviations are provided in text. Sex: C=combined, M=Male, F=Female, Mismatches in species names are due to changes in nomenclature. L_∞: asymptotic length, K: growth coefficient of the VBGF, t_0: the theoretical age when size is zero, M: natural mortality, Z: total mortality. In all of the cases, the temperature was considered equal to 17.3 ºC.

Species	Area	Year	Sex	Length type	L_{max} (cm)	L_{range} (cm)	L_∞ (cm)	K years^{-1})	t_o	T (°C)	M	Z	Reference
A. boyeri	Lake Trichonis-Lysimachia	1992-93	C	TL		4.40–10.95	11.24	0.420	-0.400	17.25	1.07	1.65	Leonardos (2001)
A. boyeri	Mesolongi Etolikon lagoons	1989-90	C	TL	10.95	1.30–10.30	11.24	0.420	-0.400	19.77	1.07	1.65	Leonardos & Sinis (2000)
A. boyeri	Mesolongi Etolikon lagoons	1989-90	M	TL	8.31	1.30–8.31	7.50	0.670	-0.460	19.77	0.41	0.93	Leonardos & Sinis (2000)
A. boyeri	Mesolongi Etolikon lagoons	1989-90	F	TL	10.30	1.30–10.30	11.99	0.230	-1.370	19.77			Leonardos & Sinis (2000)
A. boyeri	Lake Iznik	2000-01	C	TL	11.50	8.00–11.50	14.11	0.270	-0.490				Özeren (2009)
A. boyeri	Lake Iznik	2000-01	M	TL	11.00	3.00–11.00	12.11	0.330	-0.280				Özeren (2009)
A. boyeri	Lake Iznik	2000-01	F	TL	11.50	4.20–11.5	15.53	0.210	-0.730				Özeren (2009)
A. boyeri	Lake Vistonis	1989-90	C	TL	10.50	1.30–10.50	11.69	0.350	-0.990	17.50	0.95	1.29	Koutrakis et al. (2004)
A. boyeri	Lake Vistonis	1989-91	M	TL			12.80	0.260	-1.640	17.60	0.76	1.54	Koutrakis et al. (2004)
A. boyeri	Lake Vistonis	1989-92	F	TL			16.65	0.160	-1.900	17.70	0.51	0.97	Koutrakis et al. (2004)
A. boyeri	Lesina Lagoon	2013-14	C	TL		1.50–11.0	11.10	0.680	-0.050		1.48	2.24	Prato et al. (2020)
L. panosi	Lake Trichonis	1978-79	M	FL	18.80		26.20	0.124	-1.220				Daoulas (1984)
L. panosi	Lake Trichonis	1978-79	F	FL	25.80		30.00	0.113	-1.040				Daoulas (1984)
L. panosi	Lake Pamvotis	1983-84	C	FL	20.50		20.60	0.275	-1.220				Neophitou & Theochari (1989)
L. panosi	Lake Lysimachia	1991-92	C	FL	25.50	11.20–25.50	29.43	0.109	-2.720				Leonardos et al. (2005)
L. panosi	Lake Lysimachia	1991-92	M	FL								1.22	Leonardos et al. (2005)
L. panosi	Lake Lysimachia	1991-92	F	FL								0.56	Leonardos et al. (2005)
L. panosi	Lake Trichonis	1991-92	C	FL	21.70	13.10–21.70	32.39	0.084	-3.720				Leonardos et al. (2005)
L. panosi	Lake Trichonis	1991-93	M	FL								0.24	Leonardos et al. (2005)
L. panosi	Lake Trichonis	1991-94	F	FL								0.89	Leonardos et al. (2005)
S. acarnanicus	Lake Trichonis-Lysimachia	1977-79	C	TL	33.00		42.60	0.134	0.055				Iliadou (1981)
S. acarnanicus	Lake Trichonis-Lysimachia	1977-79	M	TL	27.00		34.50	0.159	-0.155				Iliadou (1981)
S. acarnanicus	Lake Trichonis-Lysimachia	1977-79	F	TL	33.00		42.60	0.136	0.094				Iliadou (1981)
S. acarnanicus	Lake Trichonis	1991-92	C	FL	31.70		39.10	0.140	-0.099	17.25	0.80	0.80	Leonardos (2004)
S. acarnanicus	Lake Trichonis	1991-92	M	FL			42.84	0.125	-0.840	17.25		1.25	Leonardos (2004)
S. acarnanicus	Lake Trichonis	1991-92	F	FL			39.65	0.134	-1.180	17.25		0.74	Leonardos (2004)
S. acarnanicus	Lake Lysimachia	1991-92	C	FL	35.40		41.07	0.137	-0.67	17.25	0.40	0.51	Leonardos (2004)
S. acarnanicus	Lake Lysimachia	1991-92	M	FL			40.72	0.139	-0.690	17.25		0.60	Leonardos (2004)
S. acarnanicus	Lake Lysimachia	1991-92	F	FL			41.06	0.137	-0.660	17.25		0.34	Leonardos (2004)
L. albanicus	Kremasta Reservoir	1982	M	FL	20.10		25.80	0.144	-0.810				Daoulas & Economidis (1989)
L. albanicus	Kremasta Reservoir	1982	F	FL	28.80		37.90	0.083	-0.900				Daoulas & Economidis (1989)
L. albanicus	Tavropos Reservoir	2005-06	C	TL	37.10	14.20–37.10	47.00	0.064	-2.760				Bobori et al. (2006)

harvesting remains the most important source of income for the local fishermen (Leonardos 2001). However, a gradual decline of the species' catches during the last two decades was declared (Tsounis & Kehayias 2021a). This could be indicative of its stock reduction and should trigger concern regarding its sustainability.

The information produced in the framework of the present study can be used for comparison reasons in future studies to reveal changes in species' exploitation rate and can be incorporated in ecosystem-based models aiming at the establishment of management and conservation measures for both the specific species and the Trichonis ecosystem.

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References

Arthington A. H., Dulvy N. K., Gladstone W. & Winfield I. J. 2016. Fish conservation in freshwater and marine realms: status, threats and management. Aquatic Conservation: Marine and Freshwater Ecosystems 26: 838–857.

Beverton R. J. H. & Holt S. J. 1956. A review of methods for estimating mortality rates in fish populations, with special references to sources of bias in catch sampling. Rapport P.-v. Réun. CIEM 140: 67–83.

Bobori D. C. & Economidis P. S. 2006. Freshwater fishes of Greece: Their biodiversity, fisheries and habitats. Aquatic Ecosystem Health & Management 9(4): 407–418.

Bobori D. C., Tsikliras A. C., Economidis N. I. 2006. Some morphological and biological characteristics of fishes from Tavropos reservoir (western Greece). Folia Zoologica (Brno) 55(2): 199–210.

Cen. 2005. EN 14757. Water quality—Sampling of fish with multimesh gillnets. European Committee for Standardization. EN 14757 Brussels.

Daoulas C. 1984. Contribution to the Biology of *Rutilus rubilio* (Bonaparte, 1837), (Pisces, Cyprinidae), in Lake Trichonis (Greece). Special Publication No 8, Institute of Oceanographic and Fisheries Research, Athens, Greece, 140 p. [in Greek]. https://okeanos-dspace.hcmr.gr/xmlui/bitstream/handle/123456789/358/No8.pdf?sequence=5&isAllowed=y

Daoulas C. & Economidis P. 1989. Age, growth and feeding of *Barbus albanicus* Steindachner in the Kremasta reservoir, Greece. Archiv für hydrobiologie 114(4): 591–601.

Douligeri A., Tsionki I., Petriki O., Moutopoulos D. K. & Stoumpoudi M. TH. 2021. Length-weight relationships and condition factors of the sand smelt *Atherina boyeri* (Risso, 1810) estimated from commercial and experimental catches in Lake Trichonis (Western Greece). Acta Adriatica 62(2): 21–44.

Freyhof J. & Brooks E. 2011. European red list of freshwater fishes. Publications Office of the European Union. Luxembourg, L.U., vii + 62 pp.

Froese R. & Pauly D. 2021. World Wide Web electronic publication. FishBase. www.fishbase.org (cited 2022 August).

Gayanilo F. C., Parre P. S. & Pauly D. 1996. The FAO ICLARM stock assessment tools (FISAT). User's guide. FAO Computerized Information Series Fisheries, Rome, p. 126.

Gulland J. A. 1983. Fish stock assessment: a manual of basic methods. Wiley, New York, p. 236.

Iliadou K. 1981. The Biology of the Fish Species *Scardinius erythrophthalmus* and *Parasilurus aristotelis* of Lakes Lysimachia and Trichonis, Greece. Doctorate Thesis, University of Patras, 180 pp.

Kehayias G. & Doulka E. 2014. Trophic state evolution of a large Mediterranean lake utilizing abiotic and biotic elements. Journal of Environmental Protection 5: 1.

Koutrakis E. T., Kamidis N. I. & Leonardos I. D. 2004. Age, growth and mortality of semi-isolated lagoon population of sand smelt, *Atherina boyeri* (Risso, 1810) (Pisces: Atherinidae) in an estuarine system of northern Greece. Journal of Applied Ichthyology 20: 382–388.

Leonardos I. D. 2001. Ecology and exploitation pattern of a landlocked population of sand smelt, *Atherina boyeri* (Risso 1810), in Trichonis Lake (western Greece). Journal of Applied Ichthyology 17: 262–266.

Leonardos, I. D. 2004. Life history traits of *Scardinius acarnanicus* (Economidis, 1991) (Pisces: Cyprinidae) in two Greek lakes (Lysimachia and Trichonis). Journal of Applied Ichthyology 20: 258–264.

Leonardos, I. D., Kagalou I., Triantafyllidis A. & Sinis A. 2005. Life history traits of Ylikiensis Roach (*Rutilus ylikiensis*) in two Greek lakes of different trophic state. Journal of Freshwater Ecology 20(4): 715–722.

Leonardos I. D. & Sinis A. 2000. Age, growth and mortality of *Atherina boyeri* Risso, 1810 (Pisces: Atherinidae) in the Mesolongi and Etolikon lagoons (W. Greece). Fisheries Research 45(1): 81–91.

Markovic D., Carrizo S. F., Kärcher O., Walz A. & David J. N. W. 2017. Vulnerability of European freshwater catchments to climate change. Global Change Biology 23: 3567–3580.

Moutopoulos D. K., Korakis A. & Katselis G. 2023. Changes of ichthyofauna in the impoundment of Aoos springs. Acta Zoologica Bulgarica 75(2): 225–233.

Neophitou C. & Theochari V. 1989. Biology of the south European roach (*Rutilus rubilio*) in Lake Pamvotida. Scientific Annals of the Department of Forestry of Natural Environment 13: 50–110.

Özeren S. C. 2009. Age, Growth and Reproductive Biology of the Sand Smelt *Atherina boyeri*, Risso 1810 (Pisces: Atherinidae) in Lake Iznik, Turkey. Journal of Fisheries International 4(2): 34–39.

Patterson K. 1992. Fisheries for small pelagic species: an empirical approach to management targets. Review of Fish Biology and Fisheries 2(4): 321–338.

Pauly D. 1979. Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. Bericthe aus dem Institut für Meereskunde an der Christian-Alberts-Universität-Kiel No 63, xv + 156 pp.

Pauly D. 1983. Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper, Rome, No. 234, viii + 52 pp.

Pauly D. 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. ICLARM Studies Review 8: 1–325.

Pauly D. & Munro J. L. 1984. Once more on the comparisons of growth in fish and invertebrates. ICLARM Fishbyte 2(1): 21.

Petriki, O., Moutopoulos D. K., Tsagarakis K., Tsionki I., Papantoniou G., Mantzouni I., Barbieri R. & Stoumboudi M. TH. 2021. Assessing the Fisheries and Ecosystem Structure of the Largest Greek Lake (Lake Trichonis). Water 13: 3329.

Prato E., Grattabliano A, Lumare D., Lumare F., Ruscito A. & Biandolino F. 2020. Growth, mortality and yield of *Atherina boyeri* Risso, 1810 from Lesina lagoon (Adriatic Sea, Italy). Acta Adriatica 61(2): 163–174.

Sparre, P., Ursin E. & Venema S. C. 1989. Introduction to tropical fish stock assessment. Part1–Manual. FAO Fisheries Technical Paper 306: 1–337.

Sun C. L., Su N. J. & Yeh S. 2003. Estimation of growth parameters and age composition for yellowfin tuna, Thunnus albacares, in the Western Pacific using the length-based MULTIFAN method [YFT-5]. Noumea, New Caledonia: SPC, Secretariat of the Pacific Community. Standing Committee on Tuna and Billfish, Mooloolaba, Queensland, Australia, 9–16 July 2003, 16th. 15 p.

Tsounis L. & G. Kehayias G. 2021a. Food and ecology or how dietary alterations can affect an aquatic ecosystem. Journal of Ethnic Foods 8: 22.

Tsounis L. & G. Kehayias G. 2021b. Alteration of the feeding behavior of an omnivorous fish, *Scardinius acarnanicus* (Actinopterygii: Cypriniformes: Cyprinidae), in the presence of fishing lights. Acta Ichthyologica et Piscatoria 51(2): 131–138.

Wootton R. J. 1998. Ecology of teleost fishes. Kluwer Academic Publishers. Dordrecht, N.L., 386 pp.

Zar J. H. 2010. Biostatistical Analysis. 5th Edition, Prentice-Hall/ Pearson, Upper Saddle River, xiii, 944 p.

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