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Technical contribution

Age, growth and mortality of scaldfish (*Arnoglossus laterna* Walbaum, 1792) from the Adriatic Sea

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Summary

The population dynamics parameters of scaldfish, *Arnoglossus laterna,* from the Adriatic Sea were studied. Specimens ranging from 4.5 to 17.1 cm in total length were collected from commercial bottom-trawl catches (2000–2006). Spawning from April through the end of August with a peak in May, *A. laterna* is one of the non-target species usually present in mixed bottom trawl catches. The overall male to female ratio was 1.00 : 0.61. The oldest individual was 6 years of age. Length–weight relationships showed positive allometric growth (b = 3.36 for males and b = 3.39 for females). Parameters of the von Bertalanffy growth equation were: L_∞ = 17.3 cm; K = 0.258 per year; t_0 = −1.0026 year; R^2 = 0.925. The relatively low value of total mortality (Z = 0.90) and relatively high value of constant rate of natural mortality (M = 0.64) was estimated. Presumed calculated fishing mortality (F = 0.26) and the consequently estimated exploitation ratio (E = 0.29) indicated no danger of an over-exploitation of this species in the study area at the current level of fishing pressure. The low T max and correspondingly high M suggest that this small benthic predator plays an important role in the Adriatic ecosystem as a prey species for large benthic predators. However, the estimates include uncertainties and require further confirmation, especially with regard to natural mortality.

Introduction

The scaldfish, *Arnoglossus laterna,* is a demersal marine fish found over mixed and muddy bottoms, at depths ranging from 10 to 200 m. The species is distributed in the eastern Atlantic, from Angola to Norway, as well as in the Mediterranean, Black and Adriatic seas (Jardas, 1996). Most *A. laterna* specimens in the Adriatic Sea were concentrated over muddy bottoms at depths around 100–150 m, being a part of the demersal fish assemblage and thus exploited mainly by bottom trawls in the continental shelf area (Jardas, 1996).

Flatfishes are an economically and ecologically critical component of benthic communities because they serve as a major energy pathway for conservation of benthic production into a form suitable for consumption by higher predators (Gibson, 2005). Within demersal fish assemblages, *Arnoglossus laterna* is considered to be a benthic predator, with evident ontogenetic changes in feed composition. Juveniles ($TL < 100$ mm) prey mainly on suprabenthic species (e.g. mysids, amphipods, and small decapods), while adults prey mainly on epibentic prey such as decapods and gobiid fish (Gibson and Ezzi, 1987; Avsar, 1993; Darnaude et al., 2001). Therefore regarding its role in trophic relationships in demersal communities, the scaldfish is considered a benthopelagic-epibentic feeder (Fanelli, 2008).

Although *A. laterna* has a widespread distribution it is not a commercially important species, thus detailed information on its biology and ecology is scarce. Most citations include the scaldfish as a part of multispecies demersal studies. Published studies encompassing populations from the NW Mediterranean and the north Irish Sea and southern North Sea include temporal and spatial distribution (Farina et al., 1997; Cabral, 2000; Letourneur et al., 2001; Prista et al., 2003; Catalan et al., 2006; Serrano et al., 2006), sexuality and spawning (Nielsen, 1986), and feeding habits (Gibson and Ezzi, 1987; Sanchezvelasco, 1998; Darnaude et al., 2001; Cabral et al., 2002; Amezcua et al., 2003). Several authors reported on studies of age and growth (Giovanardi and Piccinetti, 1983; Deniel, 1990; Djabali et al., 1993; Ozutok and Avsar, 2002; Bayhan et al., 2008), however there is no such study for scaldfish populations from the eastern Adriatic Sea fishing area.

This work is a part of multipurpose studies on the state of fish assemblages and assessment of demersal species in Croatian coastal waters. The findings will contribute to the implementation of multispecies approaches to the management of small-scale and demersal multispecies fisheries. This paper presents data on age, growth and mortality of the scaldfish, *A. laterna,* in the Adriatic Sea.

Materials and methods

All *Arnoglossus laterna* samples were collected (2000–2006) from commercial catches of local fishermen using bottom trawl nets in the Adriatic Sea, whereby 773 scaldfish were analysed. Most of the specimens were collected during their spawning season (May to August). Total length (TL) was measured for each fish with an accuracy of ± 1 mm; total body weight (W) was recorded with an accuracy of ± 0.1 g. Length data were grouped into classes of 3 mm length. Sex was determined macroscopically (male, female, undetermined). A sub-sample of 412 individuals was used for age determination. Pairs of sagittal otoliths were removed from the auditory bullae, rinsed in water to remove any tissue and stored dry for later age estimation.

The whole otoliths were fully immersed in ethanol and read by three different readers using a compound microscope (magnification 1.6 × 11.2) with a black background and under reflected light. Only 320 coincident readings of the 412

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individuals analysed were accepted. The index of average percent error (IAPE) (Beamish and Fournier, 1981) as well as the mean coefficient of variation (CV) (Chang, 1982) was calculated to estimate the relative precision between readings. Low values of the indices indicated a good precision of age estimation.

Disturbance rings on the otolith were distinguishable from annual rings based on their irregularities; disturbance rings showed thickening and were not continuous across the whole otolith. Measurements were always made along the longest axis of the otolith. Once the ring was considered to be annual, each specimen was assigned to a year-class taking into account the data of capture, the annuli counts and their formation period. Thus, the period of the ring formation (May–August) and considering 1 June as the peak of spawning (unpublished data), each fish was assigned to an age class.

The non-linear least squares regression procedure was used to estimate the growth parameters of the von Bertalanffy equation (VBGF) $TL = L_\infty (1 - e^{-k\ (t-t_0)})$, where TL is total length at age t, L_∞ is asymptotic length, k is the body growth coefficient and t_0 is theoretical age at zero length (Beverton and Holt, 1957). In addition, a power function: $W = aTL^b$, where W is total weight in g, TL is in cm and a and b are parameters, was used to describe the length–weight relationship for this species (Froese, 2006).

The Pauly (1980) empirical equation was used in this study for estimating the instantaneous natural mortality rate (M), based on growth in length and average ambient temperature. In addition, another size-related approach suggested by Gislason et al. (2008): $\ln M = a + b \ln L + c \ln L_\infty + d \ln K$ for estimating the instantaneous natural mortality rates (M) was also used. Based on the length-converted catch curve method (Sparre and Venema, 1992) for whole sample ($N = 773$), total mortality (Z) was estimated. Only fully recruited ages were used to estimate Z, as the age group at the top of the catch curve might not have been fully vulnerable to the fishing gear (Everhart et al., 1975). Also, the oldest fish were excluded, since the relationship between age and length becomes uncertain when approaching L_∞ (Sparre and Venema, 1992). Fishing mortality (F) was calculated as the difference between Z and M, and the eventual current exploitation rate was estimated as $E_{cur} = F/Z$.

Results

The 773 scaldfish individuals used in this study consisted of 460 (59.51%) males, 279 (36.09%) females and 34 (4.40%) indeterminate individuals. The male:female ratio for all fish combined was 1.00 : 0.61, showing a significantly higher portion of males than females. Length frequency distribution of the sample is shown in Fig. 1. Average size for both sexes ($TL_{avg.}$) was 8.26 ± SD 2.260 cm. Females were on average slightly longer ($TL_{females}$ = 8.51 cm ± SD 2.755 cm) than males (TL_{males} = 8.23 cm ± SD 1.923 cm), but this difference was not significant statistically (t-test: P = 0.11281). Mean weight, on the other hand, was significantly higher in females compared to males (t-test, P = 0.00350).

The weight-length relationship for males was $W = 0.0030 \times LT_{(cm)}^{3.365}$ ($R^2 = 0.979$), and $W = 0.0032 \times LT_{(cm)}^{3.372}$ ($R^2 = 0.985$) for females (Fig. 2). At the same body length, females had significantly greater weight than males (Kolmogorov–Smirnov two-sample test, P < 0.001). Values of b were significantly different (P < 0.0001) from $b = 3$, indicating a positive allometric growth.

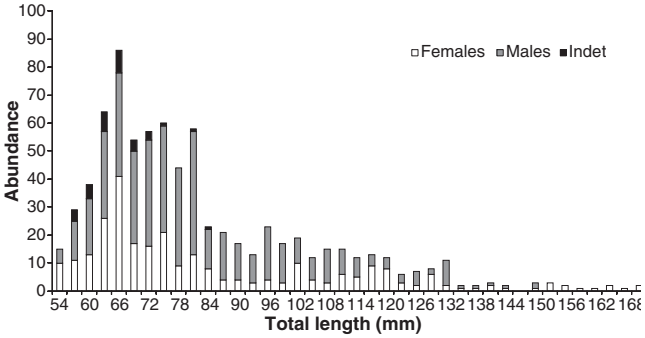

Fig. 1. Length frequency distributions of males, females and total sample (N = 773) for *Arnoglossus laterna*, Adriatic Sea

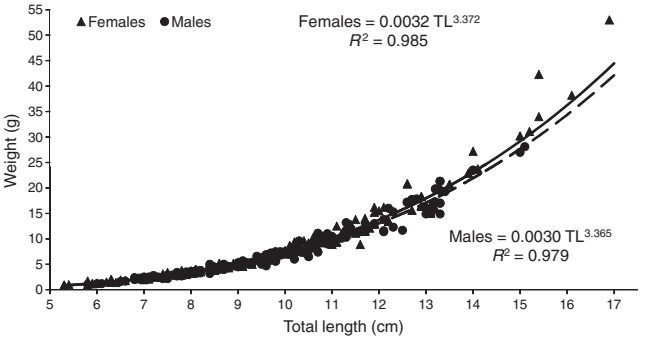

Fig. 2. Length–weight relationships of males and females for *Arnoglossus laterna*, Adriatic Sea

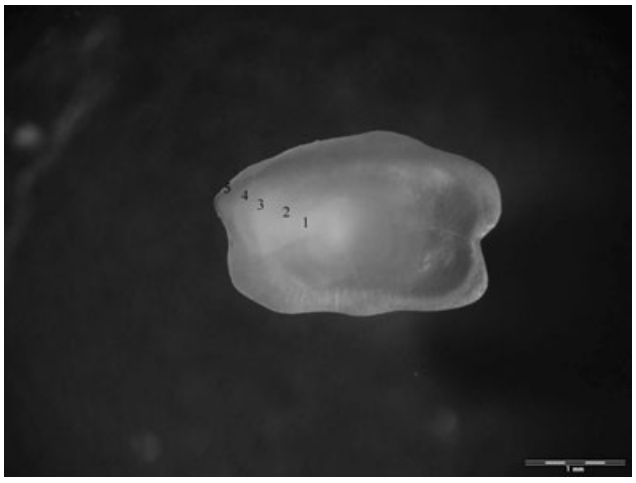

Fig. 3. A 5-year old male specimen of *Arnoglossus laterna* (TL 15 cm, W 26.98 g), Adriatic Sea

Sagittal otoliths are elongated, laterally compressed and curved. Their surfaces are irregular, with many ridges and crenulations. The external face is concave with grooves and ridges radially disposed. With age, the rostrum becomes conspicuous and curved, the sulcus acousticus becomes deeper, and the surface irregularities become more strongly marked (Fig. 3). Of the otoliths examined, 320 (77.7%) yielded useful age estimates and 92 (22.3%) were discarded, as they were either broken or difficult to interpret. The index of average percent error (IAPE) of ring counts for each reader did not differ greatly, and was slightly lower for the first reader (2.31)

than for the second (2.49) and third (2.63). The precision of the age estimates (CV) was 1.3.

Scaldfish ages ranged from 1 to 6 years, with a predominance of age classes 1 to 3 in the sample (84.1% individuals). Since differences in length at age among sexes were not significant ($P > 0.05$), nor were differences significant ($P > 0.05$) between mean ages of males and females in the sample, length-age data were pooled; eventual growth parameter estimations were considered for both sexes together. The pooled length-at-age data for *A. laterna* is given in Table 1.

Estimated von Bertalanffy growth parameters for both sexes were: $L_\infty = 17.3$ cm (SE = 0.33), K = 0.258 yr^{-1} (SE = 0.08) and $t_0 = -1.0026$ yr (SE = 0.28) ($R^2 = 0.925$; Fig. 4).

The value of natural mortality (M) obtained using the Pauly (1980) equation was 0.64, based on the above growth parameter and an average ambient temperature of 15°C (depth 0–35 m) for a given sampling area (Zore-Armanda et al., 1991). According to Gislason et al. (2008) M-vector was in range 1.35–0.32 (Table 2), based on the same parameters mentioned above (Fig. 5). From the length converted catch curve analysis, a total mortality rate (Z) of 0.90 (CI: 0.76–1.04) was estimated (Fig. 6). Fish from the first length groups (54–78 mm) were considered not yet fully recruited to the

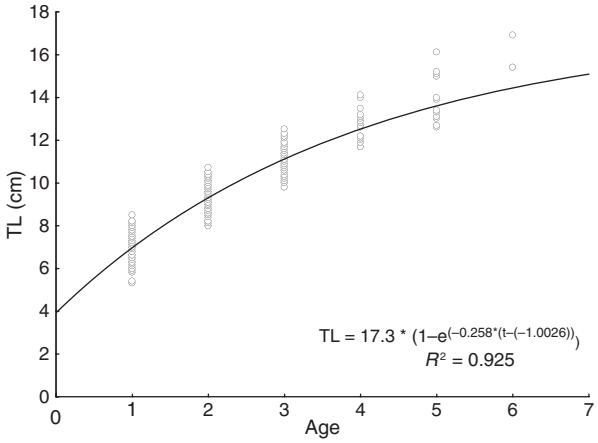

Fig. 4. Length-at age-data with fitted VBGF curve for *Arnoglossus laterna*, Adriatic Sea

Table 1
Length-at-age data for *Arnoglossus laterna* from Adriatic Sea aged using otolith readings

Length interval midpoint (mm)	Age class						
	1	2	3	4	5	6	Total
54	3						3
57	3						3
60	5						5
63	5						5
66	6						6
69	10						10
72	8						8
75	9						9
78	10	1					11
81	12	14					26
84	2	9					11
87		20					20
90		14					14
93		10					10
96		23					23
99		12	4				16
102		9	9				18
105		4	6				10
108		1	14				15
111			15				15
114			11				11
117			11	2			13
120			5	7			12
123			3	3			6
126			1	4	2		7
129				5	1		6
132				5	8		13
135				1	1		2
138				0	1		1
141				2	1		3
144					0		0
147					0		0
150					3		3
153					1	2	3
156					0	0	0
159					0	0	0
162					1	0	1
165						0	0
168						1	1
N	73	117	79	29	19	3	320
%	22.8	36.6	24.7	9.1	5.9	0.9	100.0
Mean TL	69.44	91.90	110.90	128.73	147.78	164.00	
SD TL	9.140	6.940	6.261	7.135	10.134	7.071	
Mean W	2.36	5.44	10.49	17.12	30.98	50.50	
SD W	0.810	1.284	1.946	3.725	6.890	3.536	

Table 2
Natural mortality values estimated for *A. laterna* in the Adriatic Sea

Age	Mean *TL*(cm)	Mean *W*(g)	*M* (Gislason)	*M* (Pauly)
1	6.94	2.36	1.35	0.64
2	9.19	5.44	0.84	0.64
3	11.09	10.49	0.61	0.64
4	12.87	17.12	0.48	0.64
5	14.78	30.98	0.38	0.64
6	16.40	50.50	0.32	0.64

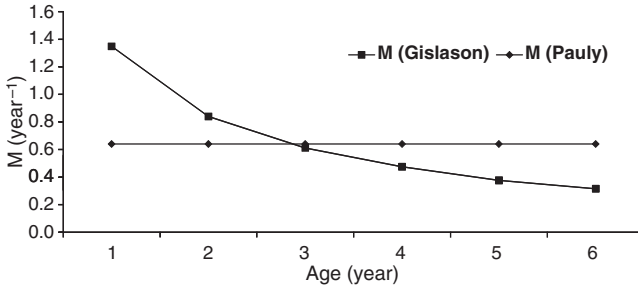

Fig. 5. M-vectors for *Arnoglossus laterna*, Adriatic Sea

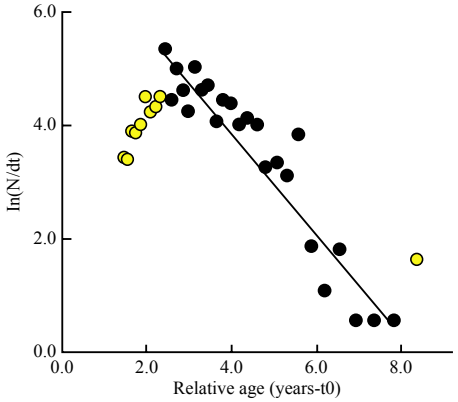

Fig. 6. *Arnoglossus laterna*, age structured catch curve for estimation of total mortality (*Z*) based on length converted catch curve (grey circles): age classes not under full exploitation and not used in the regression analysis

fishery, and therefore excluded from Z-estimation. Using this estimation of *Z* and the previously estimated value of *M* by Pauly (1980), the fishing mortality was estimated as $F = 0.26$ and the current exploitation rate as $E_{cur} = 0.29$.

Discussion

Otolith readings are the most used method for age estimation of flatfishes, although there are numerous difficulties in otolith interpretation. In the present study, besides pseudorings, the identification of the first ring turned out to be difficult. Matching results among readers was relatively high, with quite low IAPE and CV indices; but when the readers could not agree on age, this was usually due to differences in determination of the first annulus location. Furthermore, in older individuals the surface irregularities in terms of grooves and ridges complicated readings and thus required additional processing by grinding and polishing. Difficulties in recognizing the first ring can usually be related to an extended spawning period and variations in growth, rather than to possibly being hidden (Farrugio and Quignard, 1974).

There are no previous data on length-weight distribution of the *Arnoglossus laterna* population in the study area. Females were significantly heavier than males within the same length classes, probably due to well-developed ovaries. The maximum observed lengths (17.1 cm) were higher than the 16.0 cm reported by Jardas (1996); the maximum observed age was 6 years, while Deniel (1990) and Muus and Nielsen (1999) obtained a maximum age of 7.5 and 8 years for individuals of 17 cm and 25 cm, respectively (Table 3). Species from the family Bothidae are thought to live up to 10 years (Gibson, 2005). Since the oldest fish caught in the sample was 6 years of age and apparently in good condition, the authors believe that the lifespan of scaldfish in the Adriatic Sea might be up to 7 years, rather than up to 4 years as reported by Giovanardi and Piccinetti (1983). An explanation for this difference might be in the removal of the oldest fish due to higher fishing pressure made by bottom trawls on demersal fish assemblages in the western part of Adriatic Sea (Mannini and Massa, 2000), or to the fact that older fish probably inhabit deeper areas of the Adriatic Sea in the central and eastern parts.

The von Bertalanffy growth parameters estimated by other authors are given in Table 3. The parameters obtained in this study are similar to those reported by Bayhan et al. (2008) for the eastern Mediterranean (Turkish coast). But differences are obvious when compared to reported values from the western Adriatic coast (Giovanardi and Piccinetti, 1983). Growth and life span of scaldfish may in fact be different in the shallow western and deeper eastern part of the Adriatic Sea. However, differences in reported values may also be the result of incorrect age interpretation. An increased confidence in the correctness and comparability of age data is required for a more definitive conclusion.

Table 3
Biogeographic comparison of VBGF parameters for *Arnoglossus laterna*

Authors	Area	Method (age determination)	L_{max}	L_∞ (cm)	*K* (cm / year)	t_0	Age max.
Giovanardi and Piccinetti (1983)	Adriatic Sea	Scales	15 cm				
Deniel (1990)	France		17 cm	15.2 (m) 15.8 (f)	1.032 (m) 0.840 (f)	0.773(m) 0.69 (f)	7,5
Muus and Nielsen (1999)	Denmark		25 cm				8
Djabali et al. (1993)	Italy	Otoliths		15.8	0.570	0.773	
Ozutok and Avsar (2002)	Adana Bight, Turkey			15.6	0.13	−1.54	
Bayhan et al. (2008)	Izmir Bay, Turkey	Otoliths		16.87	0.236	−0.887	
Present paper	Adriatic Sea	Otoliths	17.1 cm	17.3	0.258	−1.0026	6

Estimation of a constant M by Pauly's (1980) is in good agreement with the M-vector estimated by the Gislason et al. (2008) method. Any overestimation of M would result in overestimating the potential yield of fish stocks and thus could lead to overexploitation and, ultimately, recruitment overfishing. Unfortunately, all indirect methods for estimating natural mortality may be subject to substantial bias, casting doubt on their usefulness in certain fish population studies and in the assessment of fishery exploitation (Macpherson et al., 2000 and papers therein). Thus, more credible estimations of M are required for reliable calculations of fishing mortality on a population, particularly in the Mediterranean Sea, where reliable data on the fishing effort are lacking (Bas et al., 1985), which could be useful to estimate fishing mortality and exploitation rates.

The fishing mortality and exploitation rate estimated in this study can be valued as moderate compared to other utilized stocks, but remain uncertain on basis of the given data and may well have been underestimated. Despite its low commercial value, as a by-catch species in multispecies bottom trawl fisheries, scaldfish appears to be under some fishing pressure, not yet sufficiently quantified. Thus, permanent control of fish landings, better enforcement of legislation and continued monitoring are very important and necessary for sustainable exploitation of this species in the Adriatic Sea.

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