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Growth parameters of anchovy post larvae in the Adriatic estimated from otolith growth rings

Procjena parametara rasta postlarvi brgljuna u Jadranu na osnovi broja naraštajnih prstenova u otolitima

Slobodan Regner i Jakov Dulčić

Institut za oceanografiju i ribarstvo, Split

INTRODUCTION

The destiny of larval fish stages is, according to the recent theories, essential for the recruitment of their populations. On the other hand, the knowledge of the growth rates of larval fish is indispensable for ecological studies of this important phase of life cycle of fishes, since they provide the basis for further studies of mortality, population dynamics, stock assessments, etc.

Up to the seventies the only way to estimate growth parameters of larval fish stages were the measurements of the length increase as a function of time under the controlled experimental conditions. At the beginning of seventies Pannella (1971) found that the rings present in the otoliths of fish larvae were deposed on daily basis, while Brothers *et al.* (1976) found that the rings of daily increments can be detected even in the otoliths of adult fish. Although this was discovered at the beginning of seventies, counting of daily rings in otoliths started to be widely used for the studies of the growth of larval fish stages not earlier then in the late eighties. The advantage of this method is that it does not need complicated facilities and time consuming experiments during the artificial rearing of fish larvae.

The first data on growth parameters of anchovy larvae and post larvae (post yolk — sac larvae) from the Mediterranean, obtained from measurements of length of larvae and post larvae reared in the series of experiments at constant temperature levels, carried out during the years 1976 and 1977, were given by Regner (1985). The next data on growth of anchovy larvae were given for the vestern Mediterranean by Palomera *et al.*

(1988). The length — age relationship in this case was studied using the technique of counting the number of rings of daily increments in the otoliths of anchovy larvae.

The aim of this study was to compare the parameters of growth estimated by otolith readings of the anchovy post larvae from the Adriatic Sea with those obtained from length measurements of post larvae of the exactly known age as they were reared under the experimental conditions, and to compare growth of anchovy larvae from the Adriatic with the growth of larvae from the western Mediterranean.

MATERIALS AND METHODS

The plankton samples were collected at 44 stations distributed over 10 transects perpendicular to the eastern Adriatic coast, during the cruise with the research vessel »BIOS« performed from 14. to 20. August 1989 (Fig. 1). The plankton net type BONGO with the mouth openings of 20 cm and 250 μm mesh size was used for plankton sampling. The oblique hauls were performed, and net was towed up to the maximum depth of 5 m above the bottom, at the speed between 1.5 and 2 knots.

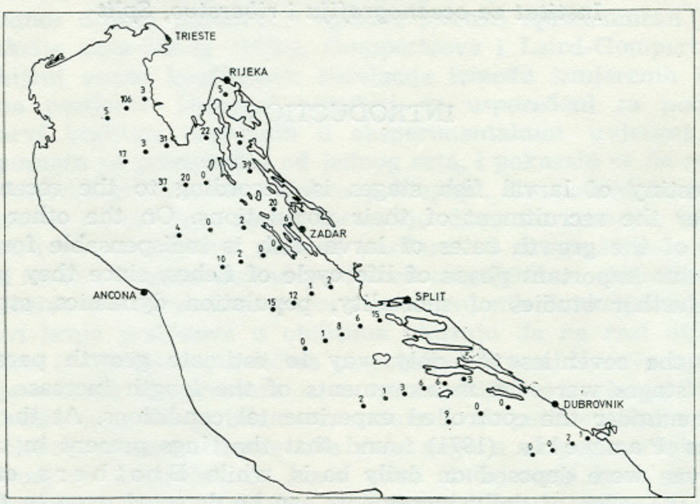

Fig. 1. The numbers of post larvae per haul **at the** stations in the surveyed area.

The plankton samples were fixed in buffered 2% formol. The anchovy planktonic stages were separated from the samples, and standard length of post larvae was measured with the accuracy of 0.01 mm. For the further estimates of length — age relationship the measured lengths were corrected for shrinkage using the linear equation whose parametrs were estimated earlier (R e g n e r, 1985).

Temperature was measured with CTD probe at every station, from the surface to the bottom, with the depth resolution of 1 m. The mean surface temperature over the surveyed area was 24.80°C. The mean temperature for the water layer from 0 to 20 m was also calculated, and it was found to be 22.63°C. In this layer the concentration of anchovy post larvae is maximum (Regner, 1972), and this temperature was considered as the mean temperature of the anchovy post larvae environment. Microzooplankton was also sampled at every station by a »Nansen« type net 45 cm diameter at the mouth, with the mesh size of 53 μm. Net was towed from 50 to 0 m.

Otoliths were removed from post larvae by fine steel needles, sagittae were rinsed in distilled water and placed in the drop of immersion oil. The counts of daily increment rings were made, depending on the size of otoliths, at the magnifications of 450 x or 600 x, at the transmitted — light microscope. The rings were counted starting from the »check ring« well described by Palomera *et al.* (1988). Otoliths were separately red by both authors, and results were compared. The discrepancy of the counts was found in only three cases, which was only 5.9% of the total number of analyzed post larvae. In this way the rings of the otoliths of 51 post larvae of various length were counted.

RESULTS AND DISCUSSION

The results of the counting of otolith rings are shown in Table 1.

Table 1. Number of daily rings and the length range of post larvae.

Number of rings (days)	No of post larvae	Length range (mm)
0	9	3.12— 3.73
1	8	3.35— 3.73
2	9	4.23— 6.13
3	1	6.51
4	7	6.13— 7.05
5	3	7.36— 7.44
6	1	9.09
8	5	9.49— 9.91
9	3	10.33—11.84
10	3	10.30—11.29
13	1	14.97
16	1	17,36

Two functions were used to express the length — age relationship of anchovy post larvae from these data. The first one was of the form:

$$l_t = a\, e^{-b\, e^{-ct}} \qquad (1), \qquad \text{Gompertz (1825)},$$

where l_t is the length of post larva in the time *t*, *a* is the asymptote, while *b* and *c* are constants. This function was used for the approximation of length — age relationship of artificially reared post larvae at the mean temperature of 21.30° C (Regner, 1980).

The second function was of the form:

$$l_t = L_o e^{(A_o/\alpha)(1 - e^{-\alpha t})}$$ (2), L a i r d *et al.* (1965),

where L_o is the length at time $t = 0$, A_o is the instantaneous growth rate at time $t = 0$, and a is the constant. P a l o m e r a *et al.* (1988) used this, so called Laird — Gompertz function, to fit the data obtained from otolith readings for Western Mediterranean anchovy post larvae.

The program FIT was used to estimate parameters of the functions (1) and (2). Besides the correlation coefficients between the estimated and measured data, the program estimates the error of the function, expressed as:

$$\epsilon_f = \frac{s}{\sqrt{N-M}}$$

where *s* is the standard deviation, N the number of data, and M number of parameters of the function.

Estimated values of the parameters of both functions are shown in Table 2.

Table 2. Estimated values of Gompertz and Laird-Gompertz functions.

Gompertz	a	b	c	r	P<	e_f
	27.315	2.0517	0.0892	0.9771	0.001	0.107
Laird-Gompertz	L_0	A_0	a	r	P<	e_f
	3.5105	0.1829	0.0891	0.9771	0.001	0.107

As it can be seen from Table 2, both functions showed the high correlation coefficients, significant at the 99.9% confidence level, with the data on length — age relationship of anchovy larvae, estimated from the counting the number of the rings in the otoliths.

The values of the asymptote *(a)* and constant *c* of the Gomperts curve are very similar to the values obtained for the same function from the data on age and length of artificially reared anchovy post larvae, since they were 27 and 0.086 respectively (R e g n e r, 1980). However, the value of constant *b* was significantly different (2.532) for the reared post larvae. The test of differences between the lengths of reared post larvae and the lengths for the same age estimated by the function (1) with the parameters obtained from the readings of otoliths gave the following results:

$$\bar{X}_{dif} = -1.71; \quad s_{\bar{x}_{dif}} = 0.3364; \quad t = 5.0832$$

As the t-test value for 7 df is is 2.36 (for $P < 0.05$), the differences between measured and estimated values are significantly different. This can also be seen from the Fig. 2, where all the lengths of reared post larvae, with the exception of the lengths for $t = 0$, and for the largest post larvae which were 14.72 days old, lay below the curve of the lengths estimated from the otolith readings.

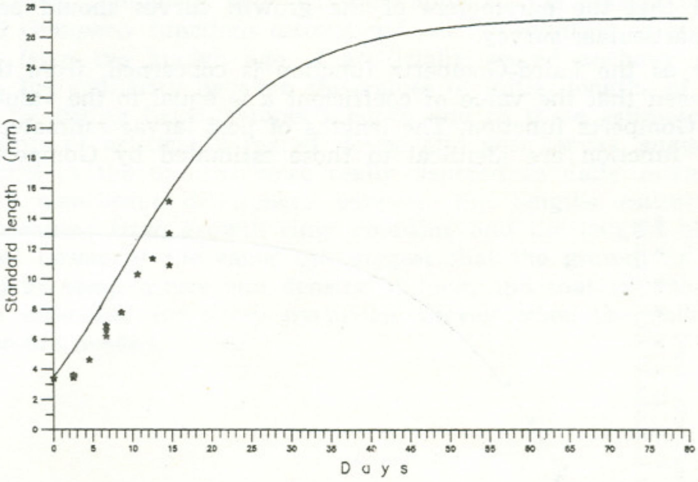

Fig. 2. The growth in length of anchovy post larvae. Asterisks = observed lengths of artificially reared post larvae (Regner, 1985); Solid line = Estimated lengths by Gompertz function whose parameters were estimated by counting daily growth rings in otoliths.

There are two possible causes of these differences. The first one is that the zones of otoliths are not deposed as daily increments. This is not very likely, since the values of the asymptotes estimated from data on reared post larvae and on otolith readings are very similar, as well as the estimated length at $t = 0$ is similar to the mean length of artificially reared post larvae in the experiment which was used for fitting Gompertz curve (Fig. 2). So, it can be supposed that in the case that counts of the rings in the otoliths were wrong, or in the case that rings were not deposed on daily basis, the difference between the length — age data and between the estimated parameters of the function (1) should be much more greater.

The second cause can be the well known fact that the growth of fish post larvae is primarily affected by the temperature and by the quantity of available food (Hempel, 1965; Theilacker and Dorsey, 1985) The anchovy post larvae which were used for fitting the growth curve with Gompertz function were reared at the mean temperature of 21.30° C, while the mean temperature of the environment of post larvae, whose otoliths were analyzed was, as mentioned before, 22.58°C. This difference of more than 1°C can be the cause of the different growth characteristics. It was also found that the mean quantity of food organisms (nauplii, copepodites and tintinnida) was 14.43 individuals/ml at the stations where post larvae were found, which was substantially higher than under the experimental conditions, wehere the mean concentration was 10 organisms/ml (R e g n e r, 1985). This can also be the cause of the higher growth rate obtained by otolith readings. So, it can be concluded that the rings in the otoliths really represent the age of post larvae in days, but that found differences show that the growth process of anchovy post larvae is very sensitive to the changes of environment. This leads to the conclusion that for every survey when the estimate of age of post larvae is needed, otoliths should be red again, and that the parameters of the growth curves should be estimated for every particulaar survey.

As far as the Laird-Gompertz function is concerned, from the Table 2 it can be seen that the value of coefficient *a* is equal to the value of coefficient *c* of Gompertz function. The lengths of post larvae estimated by Laird--Gompertz function are identical to those estimated by Gompertz function (Fig. 3).

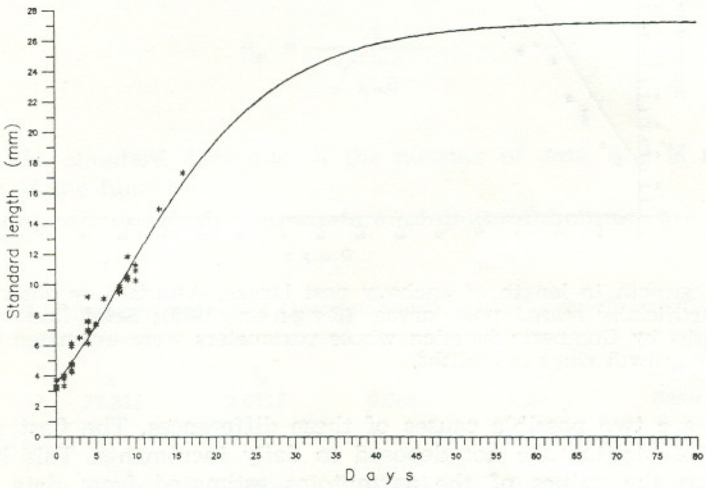

Fig. 3. Observed (asterisks) and estimated by Gompertz and Laird—Gompertz functions (solid line) growth of anchovy post larvae. Age was estimated from the number of daily growth rings in otoliths.

This means that both functions can approximate length — age relationship of post larvae with an equal precision. The estimated value of L_0 (Table 2) is practically akin to the estimated mean length at $t = O$ of artificially reared post larvae, which was found to be 3.54 mm (R e g n e r, 1985). This is another proof that the number of rings in the otoliths really indicate the age of post larvae. The estimated value of A_0 (Table 2) is very similar to that estimated by P a l o m e r a *et al.* (1988) for the western Mediterranean, who found that it was 0.1868. However, the estimated value of *a* is higher than that estimated for the western Mediterranean post larvae which was, depending whether observed or estimated by curve fitting values of L_0 were used, 0.0781 and 0.0589 respectively (P a l o m e r a *et al.*, 1988). As constant *a* is the instantaneous rate of growth rate decrease, it is evident that post larvae in the Adriatic grew slower than in the western Mediterranean.

CONCLUSIONS

The age of anchovy post larvae was estimated by the counting of number of growth rings in their otoliths. Length — age relationship was approximated by Gompertz and Laird-Gompertz functions with the high and statistically significant correlation coefficients between estimated and observed values. It was found that both functions estimated growth with an equal precision. Similarity between the values of the asymptotes and constants c of Gompertz functions estimated from the counting of otolith growth rings and from the known age of artificially reared anchovy post larvae, as well as the similarity between the values of initial lengths of post larvae estimated by fitting Laird-Gompertz curve and of those estimated from the measurements of artificially reared larvae and post larvae, suggest that the growth rings in the otoliths were really deposed as daily increments. But, statistically significant differences between the lengths estimated by the function obtained from growth rings counting and the lengths of artificially reared post larvae of the same age suggest that the growth of post larvae is affected by temperature and density of food, and that growth parameters should be estimated for every particular survey when the data on age of post larvae are needed.

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PROCJENA PARAMETARA RASTA POSTLARVI BRGLJUNA U JADRANU NA OSNOVI BROJA NARAŠTAJNIH PRSTENOVA U OTOLITIMA

Slobodan Regner and Jakov Dulčić

Institute of Oceanography and Fisheries, Split, Yugoslavia

KRATAK SADRŽAJ

Tokom krstarenja izvršenog sa m/b »BIOS« u periodu od 14. do 20. augusta 1989. godine, sakupljen je na 44 postaje uzduž istočne obale Jadrana planktonski materijal kosim potezima planktonske mreže tipa BONGO-20 Postlarve brgljuna su izdvojene iz planktonskog materijala i 51 postlarvi. čija je dužina varirala od 3.12 do 17.36 mm SL (dužine su korigirane na skupljanje u 2% formalinu) su izvađeni otoliti. Budući da je poznato da se broj prstenova u otolitima postlarvi riba povećava za jedan dnevno, izbrojan je broj prstenova u sagitama i tako procijenjena približna starost postlarvi u danima. Odnos dužina postlarvi i njihove starosti aproksimiran je pomoću dvije funkcije sigmoidnog oblika, Gompertzove i Laird-Gompertzove, pri čemu su dobijeni visoki koeficijenti korelacije između izmjerenih i procijenjenih dužina postlarvi. Dobijeni rezultati su uspoređeni sa podacima o dužini postlarvi brgljuna uzgajanih u eksperimentalnim uvjetima, čija je starost bila poznata sa preciznošću od jednog sata, i pokazalo se da se neki od parametara funkcija rasta veoma dobro poklapaju, što potvrđuje da se naraštajni prstenovi u otolitima zaista formiraju dnevnim ritmom, tako da se mogu iskoristiti za određivanje starosti postlarvi. S druge strane, statistički signifikantna razlika između dužina postlarvi uzagajanih u eksperimentalnim uvjetima i dužina postlarvi iste starosti procijenjenih funkcijama izračunatim na osnovi broja prstenova u otolitima ukazuju da na rast utječu temperatura redine i, vjerojatno, količina raspoložive hrane. Na ovo upućuje činjenica da je srednja temperatura u moru za vrijeme izvršenog krstarenja bila za 1.3°C viša nego što je bila temperatura u eksperimentalnim uvjetima, te da je i količina dostupne hrane bila veća nego u eksperimentalnim uvjetima. To navodi na zaključak da bi, u svim slučajevima kada je potrebno poznavati starost postlarvi, trebalo ponovo analizirati otolite i izračunati parametre rasta, budući da postoji velika vjerojatnoća da će se uvjeti sredine razlikovati od slučaja do slučaja.

BILJEŠKE-NOTES, izdaje Institut za oceanografiju i ribarstvo, Split; izlazi povremeno. Odgovorni urednik: Dr Mira Zore-Armanda. Naklada 600 primjeraka. Tisak: »Slobodna Dalmacija«, Split