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Growth of *Leiognathus splendens* Based on Daily Otolith Rings and Length-Frequency Analysis

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Abstract

Sagittae of *Leiognathus splendens* (Family Leiognathidae) were extracted and examined. Otolith rings were counted and increment counts were used to determine the growth of *L. splendens*. Growth parameters were estimated from the otolith increment data and the growth equation $L(t) = 14.0 (1 - \exp(-1.083 (t + 0.047)))$ was derived (where L is length in cm, K = $year^{-1}$ and t_0 in years. The age data were compared with growth curves derived from length-frequency data from Manila Bay. With L_∞ fixed at 14 cm, the age data alone yielded a value of K = 1.083 $year^{-1}$; the length data alone generated K = 0.857 and a combined analysis of the two data sets resulted in K = 0.860, implying similar shapes for the growth curves. A comparison of these values with published growth parameter estimates on *L. splendens* establishes that the otoliths of *L. splendens* are deposited, on the average, at the rate of one increment per day.

Introduction

Estimating the age of fish forms an essential part of their assessment and management. It is usually necessary to derive mathematical models of both growth and mortality (Gjøsaeter et al. 1984; Ralston 1976). Growth rate data are essential for production estimates. Detailed age and growth studies are also important in determining the age structure of the population, the age at first maturity, and individual and population growth responses to environmental changes. These data, whether of basic life-history nature or directly applicable to fish stock assessment, all contribute to an understanding of the biology of fishes (Brothers 1980).

Daily otolith rings were first described by Panella (1971). Since then, various studies have confirmed the daily nature of such rings (Brothers et al. 1976; Brouard et al. 1984; Mangaoang 1982; Ralston 1976).

This study aimed to estimate the age and growth rate of *L. splendens* (Family Leiognathidae) based on daily otolith ring counts as related to size and to test the assumption that otolith rings are deposited daily through comparison with estimated growth parameters obtained through analysis of length-frequency data.

Materials and Methods

Fish samples were collected from the following sites (Luzon, Philippines): Tanza, Cavite (June 1986); Malabon terminal market (September 1986); Hulo market (October 1986-February 1987); Navotas Fishport (February 1987). A total of 980 fish was collected and examined.

All three pairs of otoliths namely sagittae, lapilli and asterisci have rings that can be counted. Sagittae, being the biggest, were used for this study.

Each fish was weighed and measured immediately after collection, labelled and frozen in individual plastic bags.

After extraction using a fine forceps, each pair of sagittae was placed in 70% ethyl alcohol for one to two days, then cleaned of adhering tissues in tap water by teasing the otolith under a stereomicroscope using a fine dissecting needle. Afterwards, the cleaned sagittae were placed in vials with a few drops of ethyl alcohol for 24 hours for further clearing and dehydration, then mounted on slides and air-dried for one day. The sagittae were examined individually in a drop of immersion oil under a light microscope.

Otolith increments were counted directly on the mounted sagittae with the concave side upwards under 400x magnification. Counting was done starting from the core or nucleus towards the tip with most identifiable rings. Each sagitta was counted twice using a hand counter. Readings were recorded separately. The mean of the two readings was used for analysis.

The otolith increment readings were compared with growth curves obtained from the age data and growth curves derived from length-frequency data. Here, data collected by Donaldo (1979) were used. The data, consisting of male and female *L. splendens* were pooled to make them compatible with the otolith-increment data which were obtained from fish that had not been sexed.

Fitting of the growth curve to the length-frequency data was done using the ELEFAN I computer program of Pauly and David (1981). Parameter estimation was performed after the length-frequency data had been corrected for selection effects, following the method of Pauly (1986).

On the assumption that one ring is equal to one day's growth, the von Bertalanffy growth equation was fitted to the growth increment data.

The growth parameters L_∞, K, and t_0 were estimated using the ETAL I program (Gaschütz et al. 1980) which allows the fitting of growth curves of the von Bertalanffy type to any set of weight- or length-at-age data.

Based on the growth curve fitted to the daily age readings, growth increment data resembling tagging/recapture data were identified as required for the method of Morgan (1987) in Gayanilo et al. (1988). This method, which is basically similar to the ELEFAN I program identifies an optimum combination of growth parameters, i.e., the combination which maximizes the mean of two goodness-of-fit estimators pertaining to the length data and to the age data, respectively.

Results

The nucleus of the sagittae in *L. splendens,* which appears as a black dot, is located anteriorly just behind the two rostra. Around this nucleus, the sagittal increments are deposited concentrically. The nuclear region has 21-24 rings. The thickness of each ring of the first 7-8 rings is uniform. As the rings progress towards the postrostrum, there is a gradual increase in the width of the increments which become uniform up to the middle and then gradually decrease again up to the edge of the otolith. In smaller otoliths, the width of each increment is relatively uniform from the 24th ring to the edges. The width of the increments on the rostral side is usually bigger than those facing the postrostral side. These rings gradually become smaller as they progress towards the edge. The surface of the otolith is irregular and is accentuated by a series of ridges.

One light band plus one dark band were together considered to represent one "ring" or primary growth increment (Panella 1971, 1974), considered to be deposited daily.

Major patterns consisting of 7-8 rings or 14-16 rings were considered to be weekly and fortnightly patterns, respectively. These patterns were found to occur regularly in most of the otoliths examined. These major patterns are usually separated from each other by dark bands or areas of discontinuity (Brouard et al. 1984). These areas have been referred to as "growth interruptions" by Panella (1974). Sometimes, an irregular pattern of 5-6 rings or 21-28 rings were observed. Also, 3-4 rings were observed within a primary growth ring and these were assumed to be subdaily; they tend to disappear with the change in the focus of the microscope. These rings were not included in the counts.

The numbers of rings counted within otoliths are summarized in Table 1, where the mean number of rings for each fish has been rounded to the nearest integer. The calculated growth equation for this data set is:

$$L_t = 16.5\,(1 - \exp(-0.734\,(t + 0.157)) \quad \ldots 1)$$

However, a value of L_∞ = 16.5 cm (standard length) seems too high for *L. splendens*. Hence, a forcing value of L_∞ = 14.0 cm (14.0 cm is the maximum recorded length for the species) was used and a second growth curve was then fitted to the data. The growth equation thus became:

$$L_t = 14.0\,(1 - \exp(-1.083(t + 0.047))) \quad \ldots 2)$$

The calculated growth curves as fitted to the data are shown in Fig. 1.

For the length-frequency data, a fixed L_∞ = 14.0 cm was also used, which resulted in an estimate of K = 0.857, as determined by varying K in small steps (see Fig. 2).

Fig. 3 shows the plot of the goodness of fit *vs.* the value of the parameter K. As might be seen, the best K value, i.e., 0.860 (corresponding to a goodness of fit value = 0.736) is extremely close to the value of K = 0.857 estimated from the length data alone and is in fact comprised of the latter estimate combined with that obtained using the age data alone (K = 1.083).

Table 1. Rings counted in the otoliths of *Leiognathus splendens*.

Otolith no.	Date of collection	Standard length (cm)	Ring count		Mean number of rings
			First	Second	
1	28 Feb 1987	5.8	158	167	162
2	4 Dec 1986	5.9	154	159	156
3	4 Dec 1986	6.0	176	167	170
4	28 Feb 1987	6.1	165	176	171
5	27 Sep 1986	6.2	165	176	171
6	24 Sep 1986	6.3	179	171	175
7	4 Dec 1986	6.4	168	175	172
8	24 Sep 1986	6.5	182	185	184
9	4 Dec 1986	6.7	177	188	183
10	3 Oct 1986	6.7	182	180	181
11	24 Sep 1986	6.9	189	186	192
12	14 Jan 1987	7.0	226	233	230
13	29 Jun 1986	7.0	213	197	205
14	29 Jun 1986	7.0	245	231	238
15	29 Jun 1986	7.0	235	235	235
16	29 Jun 1986	7.1	213	218	216
17	14 Jan 1987	7.1	234	246	240
18	29 Jun 1986	7.1	236	230	233
19	14 Jan 1987	7.2	241	241	241
20	29 Jun 1986	7.2	237	242	240
21	14 Jan 1987	7.3	238	251	244
22	29 Jun 1986	7.5	253	273	263
23	29 Jun 1986	7.6	249	246	248
24	29 Jun 1986	7.8	264	261	262
25	24 Sep 1986	8.0	273	275	274
26	27 Sep 1986	8.0	271	273	272
27	3 Oct 1986	8.3	281	274	278
28	3 Oct 1986	8.3	296	287	292
29	3 Oct 1986	8.5	290	292	291
30	27 Sep 1986	8.5	314	322	318
31	3 Oct 1986	8.8	357	355	356
32	12 Feb 1987	10.0	401	406	404
33	12 Feb 1987	10.2	427	435	431
34	12 Feb 1987	10.6	440	424	432
35	12 Feb 1987	11.0	446	456	451

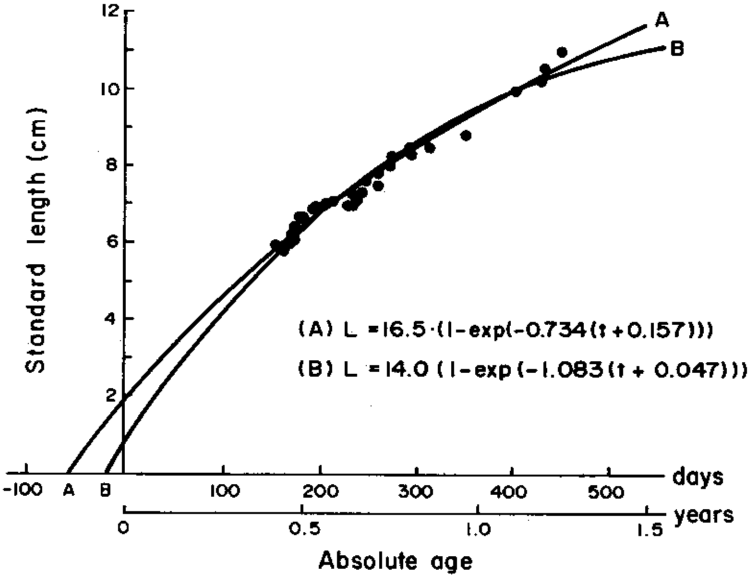

Fig. 1. Calculated growth curves for *L. splendens* fitted to the otolith increment data.

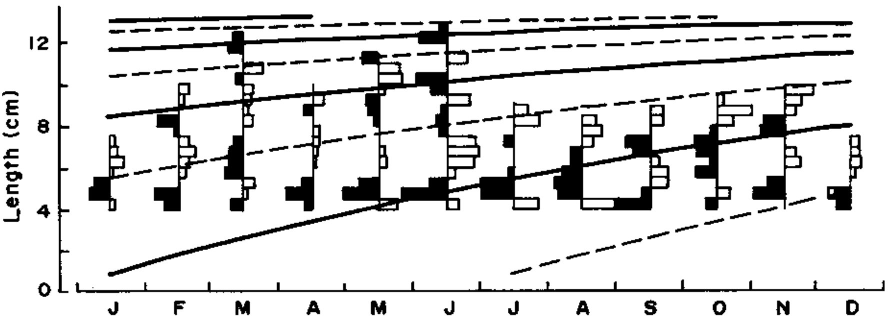

Fig. 2. Growth curves for *L. splendens* superimposed over the restructured length-frequency data of Donaldo (1979) using the method of Pauly and David (1981).

Discussion

The usefulness of the von Bertalanffy growth equation to assess the daily nature of increments in otoliths of tropical fishes has been demonstrated by Ralston (1976), Gjφsaeter and Sousa (1983) and

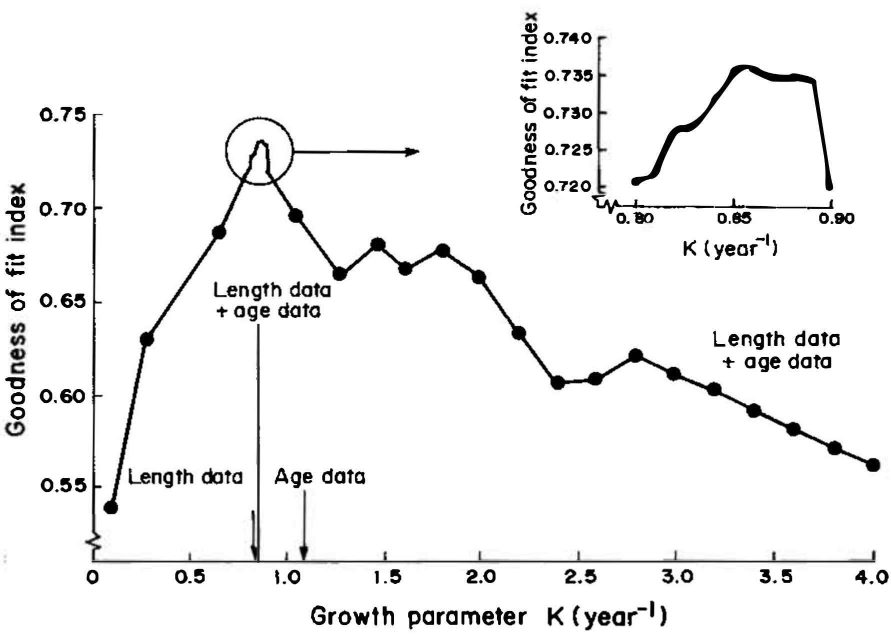

Fig. 3. Relationship between K (for L_∞ fixed at 14.0 cm) and the goodness of fit of the length-frequency and age data. Note presence of a well-marked peak (insert) and the fact that the optimum K value of the combined data set lies between the best K values estimated separately from the length-at-age data.

others. In cases when no rearing or other rigorous validation methods can be used, length-frequency analysis has been suggested by Brothers (1980) and Gjφsaeter et al. (1984) as a method for validation of daily rings.

In this study, a relatively new method, based on length-frequency analysis, was used to assess further the growth increment readings. This method, based on approach suggested by Morgan (1987), analyzes length-frequency data simultaneously with age data (in the form of "tagging/recapture", i.e., growth increment data). The method can be used to assess the reliability of growth parameter estimates derived from the length-frequency data and age data.

Based on the otolith increment data alone, the estimated L_∞ = 16.5 cm seems to be too high for a fish with a maximum recorded length of only 14.0 cm SL (Rau and Rau 1980). Possibly, errors in counting rings caused an underestimation in the age of the larger fish (SL = 10.5 cm and above), since as the fish grows older, the growth increments become less defined (Mangaoang 1982; Ralston 1976). A

Table 2. Comparison of growth parameters of *L. splendens* contained using the otolith increment technique with similar studies using length-frequency analysis.

Method	Area	L_∞	K	ϕ'^{a}
Otolith increment technique + length-frequency analysis	Manila Bay	14.0	0.86	2.27
Otolith increment technique	Manila Bay	14.0	1.083	2.33
Length-frequency analysis				
a) data of Donaldo 1979	Manila Bay	14.0	0.857	2.23
b) Corpuz et al. 1985	Ragay Gulf	12.25	0.89	2.12
c) Corpuz et al. 1985	Samar Sea	14.95	0.96	2.33
d) Silvestre 1986	Samar Sea	12.1	0.90	2.19
e) Ingles and Pauly 1984	Manila Bay (1957-1959)	12.4	0.75	2.06[b]
f) Ingles and Pauly 1984	Manila Bay (1958)	13.2	0.76	2.12
g) Ingles and Pauly 1984	Manila Bay (1959-1960)	12.3	0.70	2.02[b]
h) Ingles and Pauly 1984	Samar Sea (1979-1980)	15.0	0.73	2.24
i) Pauly 1980	Indonesia	14.3	1.04	2.32
			Mean	2.24

[a] $\phi' = \log_{10} K + 2\log_{10} L_\infty$ (K, year^{-1}; L_∞, cm) (Pauly and Munro 1984).
[b] Values appear to be too low, not used for computing mean.

forced value of L_∞ = 14.0 seems to be a more reliable estimate of asymptotic length for *L. splendens*. A joint analysis of the age data and length-frequency data with a fixed L_∞ = 14.0 cm resulted in K = 0.860. Upon comparison with the values of the growth constant K (which determines the rate at which L(t) is approaching L_∞), it can be seen that these values (K = 1.083 for the age data, K = 0.857 for length-frequency data and K = 0.860 for both age and length-frequency data) are close to each other (see Fig. 3), implying growth curves with very similar shape and hence, similar growth rates. This result indicates that the otolith rings are indeed daily in occurrence. This confirms previous studies on otolith rings of tropical fishes (Brothers 1980; Brothers et al. 1976; Brouard et al. 1984; Ralston 1976; Struhsaker and Uchiyama 1976). Also, comparing the results with growth parameter estimates of *L. splendens* from various fishing areas, it can be seen that the available growth parameters as a whole generate similar values of the growth performance index ϕ' of Pauly and Munro (1984) (Table 2).

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References

Brothers, E.B. 1980. Age and growth studies of tropical fishes, p.119-136. *In* S.B. Saila and P.M. Roedel (eds.), Stock assessment for tropical small-scale fisheries. Proceedings of the International Workshop held on 19-21 September 1979 at the University of Rhode Island, Kingston, RI.

Brothers, E.B., C.P. Mathews and R. Lasker. 1976. Daily growth increments in otoliths from larval and adult fishes. U.S. Fish. Bull. 74(1): 1-8.

Brouard, F., R. Grandperrin, M. Kulbicki and J. Rivaton. 1984. Note on observations of daily rings on otoliths of deepwater snappers. ICLARM Translations 3, 8 p. International Center for Living Aquatic Resources Management, Manila, Philippines.

Corpuz, A.B., J. Saeger and V. Sambilay. 1985. Population parameters of commercially important fishes in Philippine waters. Dept. Mar. Fish. Tech. Rep. 6: 1-99.

Donaldo, S.S. 1979. Contributions to the biology of common slipmouth, *Leiognathus splendens* (Cuvier, 1829) caught from Manila Bay. University of the Philippines, Diliman Quezon City. 55 p. M.Sc. Thesis.

Gaschütz, G., D. Pauly and N. David. 1980. A versatile BASIC program for fitting weight and seasonally oscillating length growth data. ICES C.M. 1980/D: 6.

Gjφsaeter, J., P. Dayaratne, O.A. Bergstad, H. Gjφsaeter, M.I. Sousa and I.M. Beck. 1984. Ageing of tropical fish by growth rings in the otoliths. FAO Fish. Circ. 776. 54 p.

Gjφsaeter, J. and M.I. Sousa. 1983. Reproduction, age and growth of the Russell's scad *Decapterus russelii* (Rüppell, 1828) (Carangidae) from Sofala Bank, Mozambique. Rev. Inv. Pesq. Maputo 8: 83-104.

Gayanilo, F.C. Jr., M. Soriano and D. Pauly. 1988. A draft guide to the Compleat ELEFAN. ICLARM Software 2, 65 p. International Center for Living Aquatic Resources Management, Manila, Philippines.

Ingles, J. and D. Pauly. 1984. An atlas of growth, mortality and recruitment of Philippine fishes. ICLARM Tech. Rep. 13, 127 p. Institute of Fisheries Development and Research, College of Fisheries, University of the Philippines in the Visayas, Quezon City, Philippines, and International Center for Living Aquatic Resources Management, Manila, Philippines.

Mangaoang, I.D. 1982. Age and growth of three species of *Siganus* in the wild and in captivity: a comparative study based on their daily otolith rings. University of the Philippines, Diliman, Quezon City. 88 p. M.Sc. Thesis.

Morgan, G.R. 1987. Incorporating age data into length-based stock assessments, p. 137-146. *In* D. Pauly and G.R. Morgan (eds.) Length-based methods in fisheries research. ICLARM Conference Proceedings 13, 468 p. International Center for Living Aquatic Resources Management, Manila, and Kuwait Institute for Scientific Research, Safat, Kuwait.

Panella, G. 1971. Fish otoliths: daily growth layers and periodical patterns. Science 173: 1124-1127.

Panella, G. 1974. Otolith growth patterns: an aid in age determination in temperate and tropical waters, p. 28-39. *In* T. B. Bagenal (ed.) The ageing of fish. Unwin Brothers Ltd., Surrey.

Pauly, D. 1980. The use of a pseudo-catch curve for the estimation of mortality rates in *Leiognathus splendens* (Pisces, Leiognathidae) in Western Indonesian waters. Meeresforch. 28: 56-60.

Pauly, D. 1986. On improving operation and use of the ELEFAN programs. Part III. Correcting length-frequency data for the effects of gear selection and/or incomplete recruitment. Fishbyte 4(2): 11-13.

Pauly, D. and N. David. 1981. ELEFAN I, a BASIC program for the objective extraction of growth parameters from length-frequency data. Meeresforsch. 28: 205-211.

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

Ralston, S. 1976. Age determination of a tropical reef butterflyfish utilizing daily growth rings of otoliths. U.S. Fish. Bull. 74: 990-994.

Rau, N. and A. Rau. 1980. Commercial fishes of the Philippines. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn, Federal Republic of Germany.

Silvestre, G.T. 1986. Assessment of the multispecies demersal stock of the Samar Sea, Philippines. Tech. Rept. No. 7. Dept. of Marine Fisheries, College of Fisheries, University of the Philippines in the Visayas. 65 p.

Struhsaker, P. and J. Uchiyama. 1976. Age and growth of nehu *Stolephorus purpureus* (Pisces:Engraulidae) from the Hawaiian Islands as indicated by daily growth increments of sagittae. U.S. Fish. Bull. 79: 459-465.

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