Growth and Length-Weight Parameters of Pacific Mackerel (*Scomber japonicus*) in the Gulf of Guayaquil, Ecuador

E. Cucalón-Zenck

Abstract

The seasonally oscillating growth parameters and length-weight relationship for *Scomber japonicus* caught in the Gulf of Guayaquil, Ecuador, were determined based on length-frequency data from 1989 to 1996, using the FiSAT software package of Gayanilo et al. (1996). Estimates of growth parameters are in general agreement with previous studies on the same species. Results also imply that the growth of *S. japonicus* slows down during the cold season by approximately 50% with respect to the average growth. The mean value of the power b is significantly larger than 3, indicating that the model of allometric growth should be used for the length-weight relationship and calculation of the condition factor.

Introduction

In Ecuador, the activity of the pelagic fishery is centered in the Gulf of Guayaquil. The average annual catch of small pelagic fish was about 400 000 t during the period 1989 to 1996. A map of the area including the main landing places is presented in Fig. 1. Posorja is the most important with nearly 50% of the annual landings of small pelagic fish.

The pelagic fish stocks in Ecuador are mainly exploited by purse seiners. This gear accounts for more than 90% on the total landings. The catches of small pelagic fish consist of a mixture of species, such as the Pacific mackerel (*Scomber japonicus*), Pacific sardine (*Sardinops sagax*), jack mackerel (*Trachurus murphyi*), Pacific thread herring (*Opisthonema* spp.), southern anchovy (*Cetengraulis mysticetus*), frigate mackerel (*Auxis thazard*), round herring (*Etrumeus teres*). Of these, the Pacific mackerel is the most important. The biology of the species in this area, including the estimation of growth parameters, has yet to be fully documented. This paper attempts to improve previous assessments by inclusion of length-frequency data from 1989 to 1996 to estimate the growth and length-weight parameters for *S. japonicus* (Scombridae) caught in the Gulf of Guayaquil. The FiSAT software package of Gayanilo et al. (1996) was used for the analysis.

Materials and Methods

Length-frequency data were obtained from nearly 50 000 fish ranging

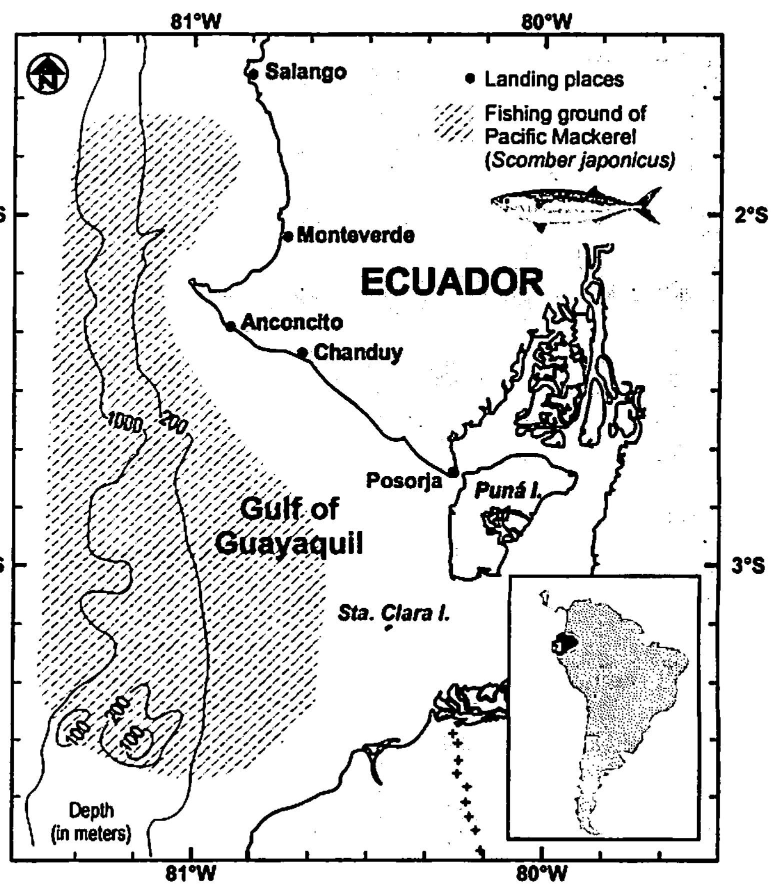

Fig. 1. Main landing places of small pelagic fishes and main fishing ground of S. japonicus in the Gulf of Guayaquil, Ecuador.

in size from 9 cm to 37 cm collected from commercial vessels in the Gulf of Guayaquil from 1989 to 1996. Each time, a random sample of around 20 kg was taken from a vessel before the catch was sorted and landed. The first step was to separate *S. japonicus* from other species. The subsample of Pacific mackerel was then collected for analysis in the laboratory specifying length (mm), weight, sex and maturity. Fork length was measured to the nearest cm.

During the study period, data collection was concentrated in Posorja and Monteverde, the principal landing places for purse seine fisheries in the Gulf of Guayaquil. It was assumed that data collected from both ports were representative of the population of Pacific mackerel in the area concerned. Samples were collected at the landing sites from 15 to 25 trips per month. Data collection during this period was carried out as part of a major fisheries research project conducted by four major fishing companies of Ecuador.

The ELEFAN I program incorporated in the FiSAT software was used for estimating the growth parameters of the von Bertalanffy growth equation. This program transforms the original length-frequency data into restructured length frequencies where peaks are assumed to represent individual cohorts and the best fit of a von Bertalanffy growth curve is obtained iteratively. The criterion for optimizing the fit of the growth curve is the ratio (R_n) between the number of positive points (peaks) through which the curves pass relative to the total number of positive points available in the set of length-frequency data (Ingles and Pauly 1984).

Correction of the original length-frequency data for the effects of gear selection and gradual recruitment to the fishery area (Pauly 1986) was attempted using the probability of capture given by the length-converted catch curve method also incorporated in FiSAT. However, since the mean growth parameters obtained from the corrected data were not significantly different from those estimated from the uncorrected data and the fitting of the growth curve did not show any improvement, the growth parameters obtained from the uncorrected data were considered the final estimates in this work.

In order to investigate seasonally oscillating growth, a von Bertallanfy growth equation of the form (Pauly and Gaschütz 1979):

$$L(A)=L_\infty[1-e^{-K(A-t_0)-CK/(2\pi)\sin 2\pi(A-t_s)}] \quad ...1)$$

was used. Here, L_∞, K and t_0 are the von Bertalanffy growth parameters, C is the amplitude of the seasonal oscillation in growth rate and t_s is the so-called Summer Point. The point of slowest growth within the year is called the Winter Point (WP) and is equal to $t_s + 0.5$.

In order to compare different estimates of growth parameters, the empirical equation of Pauly and Munro (1984) was used:

$$\phi' = \log K + 2 \log L_\infty \quad ...2)$$

The ϕ' concept refers to the finding that, provided L_∞ is expressed as total length in cm and K in year^{-1}, the quantity ϕ' is normally distributed within a given fish species with different populations, each of which may have different but mutually compatible values of L_∞ and K (Pauly and Munro 1984).

The length-weight relationship of *S. japonicus* was determined using the equation:

$$W = a\, FL^b \quad ...3)$$

where W is weight of an individual fish in g, and FL is fork length of an individual fish in cm. A total of 7 157 fish ranging in length from 12.5 cm to 37.4 cm were studied for this purpose. Using the logarithmic transformation:

$$\log W = \log a + b \log FL \quad ...4)$$

where a and b are constants estimated by linear regression of the log-transformed variates, using the LOTUS 1-2-3 linear regression routine. The condition factor, defined as c.f.=W 100/FL^b, was also calculated. All results are presented on a per-year basis for the 1989–1996 period.

Results and Discussion

TOTAL LENGTH-FORK LENGTH RELATIONSHIP

Since the original length data were measured as fork length, conversion of fork length (FL) to total length (TL) was necessary before calculation of the growth performance index. Thus, the relationship between TL and FL was obtained by linear regression from length measurements of 400 specimens of *S. japonicus* randomly collected.

The estimated model is:

$$TL = 0.09 + 1.1\, FL \; (r=0.989) \quad ...5)$$

where TL and FL are measured in cm.

GROWTH AND SEASONAL OSCILLATIONS

Overall, the growth curves fitted by ELEFAN I represent a rather poor fit to the peaks in the restructured data. The goodness of fit R_n, that can reach a maximum of 1, is generally low, ranging from a minimum of 0.228 to a maximum of 0.439. The relatively poor fit of the growth curves is probably a result of spawning all year round and the effects of seasonal growth.

Table 1 shows the growth parameters estimates FL_∞, K, and C and WP as well as the growth performance index ϕ' on a per year basis for the 1989-1996 period. The yearly values correspond to average growth observed for the different cohorts present in any year. The mean values for the study period were FL_∞=45.0 cm, K=0.37 year^{-1}, C=0.48 and WP=0.64, giving $\phi'=2.95$. Thus, for *S. japonicus* the seasonally oscillating version of the von Bertalanffy growth equation becomes:

$$FL(A)=45.0[1-e^{-0.37(A-t_0)-(0.48)(0.37)/(2\pi)\sin(2\pi(A-0.14))}] \quad ...6)$$

Estimated values of FL_∞ and K from different studies are presented in Table 2. The estimated average value of K=0.37 is well within the range of 0.16-0.47 reported by various authors and in other areas of the eastern Pacific, being very close to that obtained by Morales-Nin (1988) based on hard structures. Our average estimate of FL_∞=45.0, although slightly larger than those reported by other studies, is in reasonable agreement with the maximum length (40 cm FL) ever recorded in the study area.

If one assumes that longevity $t_{max} \approx 3/K$ (Pauly 1983), we obtain $t_{max} \approx 8$ years, which is equal to the highest age reported for *S. japonicus* in the Gulf of Guayaquil by Maridueña (1994) based on otolith readings, but below the maximum age of 10 years reported for the same area by Menz and Pizarro (1988).

By running ELEFAN I and allowing for seasonal oscillations in growth rate, slightly better fits were obtained. The increase in goodness of fit was on average 25%, which indicates the importance of seasonality in growth. Our results imply that the growth of *S. japonicus* slows down during the cold season (July-August) by approximately 50% with respect to the average growth. On the other hand, the differences of (monthly mean) sea surface temperature between the summer and winter in the Gulf of Guayaquil and the adjacent area extending farther offshore reach 4°C–5°C and are thus sufficient to generate the observed value of C (Pauly 1982).

Values of ϕ' obtained by various authors in the eastern Pacific region

Table 1. Growth parameters estimates for* S. japonicus *from the Gulf of Guayaquil, Ecuador (1989-1996).

Year	FL_{max}[a] (cm)	FL_∞[a] (cm)	K ($year^{-1}$)	C	WP	ϕ'[b,c]	n
1989	35	44.6	0.36	0.15	0.75	2.94	11 126
1990	37	44.6	0.34	1.00	0.88	2.92	7 863
1991	36	45.3	0.41	0.45	0.95	3.01	16 758
1992	35	46.3	0.30	0.10	0.70	2.89	2 006
1993	36	47.0	0.51	1.00	0.30	3.14	4 387
1994	37	44.8	0.34	0.25	0.65	2.92	2 048
1995	36	44.0	0.38	0.80	0.25	2.95	1 758
1996	35	43.3	0.32	0.10	0.65	2.86	1 011
mean		45.0(±1.0)[d]	0.37(±0.05)[d]	0.48(±0.33)[d]	0.64(±0.21)[d]	2.95(±0.07)[d]	

[a] FL = Fork Length
[b] $\phi' = \log K + 2 \log L_\infty$ (Pauly and Munro 1984)
[c] After converting FL_∞ to TL_∞ by using equation (5)
[d] 95% confidence interval

Table 2. Various estimates of growth parameters for* S. japonicus *in the eastern Pacific region.

Method/Area	FL_∞[a] (cm)	K ($year^{-1}$)	C	WP	ϕ'[b,c]	Sources
Length-based Methods						
Ecuador	40.0	0.18	-	-	2.54	Dawson (1986)
Ecuador	37.4	0.47	0.36	0.14	2.90	Morales-Nin (1988)
Ecuador	38.0	0.41	-	-	2.86	Menz and Pizarro (1988)
California	43.6	0.24	-	-	2.74	Parrish and MacCall (1978)
Hard Structure Analysis						
Peru	40.6	0.41	-	-	2.92	Mendo (1984)
Chile	44.4	0.16	-	-	2.58	Aguayao and Steffens (1986)
Ecuador	39.2	0.23	-	-	2.63	Pizarro (1983)
Ecuador	40.5	0.21	-	-	2.62	Dawson (1986)
Ecuador	39.9	0.20	-	-	2.59	Menz and Pizarro (1988)
Ecuador	39.6	0.39	0.36	0.14	2.87	Morales-Nin (1988)
mean					2.73	

[a] FL = Fork Length
[b] $\phi' = \log K + 2 \log L_\infty$ (Pauly and Munro 1984)
[c] After converting FL_∞ to TL_∞ by using equation (5)

Table 3. Length-weight (FL, cm-g) parameters estimates of* S. japonicus *from the Gulf of Guayaquil, Ecuador (1989-1996).

Year	a	b	n	r[a]	FLmax[b] (cm)	FLmin[b] (cm)	c.f.[c]
1989	0.00700	3.194	1207	0.987	35.0	17.3	0.45
1990	0.00416	3.363	844	0.992	35.5	14.8	0.51
1991	0.00297	3.449	1580	0.991	36.5	12.5	0.48
1992	0.00774	3.168	911	0.981	35.4	18.2	0.46
1993	0.00405	3.373	1251	0.976	36.3	20.0	0.47
1994	0.00435	3.352	782	0.988	37.4	15.9	0.46
1995	0.00407	3.342	662	0.936	36.5	22.5	0.40
1996	0.00183	3.569	311	0.911	35.8	22.2	0.38
mean	0.00452	3.351(±0.109)[d]					

[a] r = correlation coefficient
[b] FL = Fork Length
[c] c.f. = condition factor
[d] 95% confidence interval

Table 4. Various estimates of length-weight (FL, cm-g) parameters of S. japonicus in the southeastern Pacific region.

Area/Year	a	b	Remarks	Sources
Ecuador				
1982	0.000013	3.001		Pizarro (1983)
1982	0.000016	2.956		Menz and Pizarro (1988)
1983	0.000010	3.020		Menz and Pizarro (1988)
1984	0.0000004	3.627		Menz and Pizarro (1988)
Peru				
1980	0.20302	2.141	Stock norte	Dioses (1985)
1980	0.01459	2.959	Stock sur	Dioses (1985)
1983	0.02068	2.821	Stock norte	Dioses (1985)
1983	0.02109	2.807	Stock sur	Dioses (1985)
Chile •				
•	0.00291	3.423		Aguayao et al. (1982)

were used for comparison with the estimates obtained here. The average value of ϕ' obtained with the estimated growth parameters with seasonality compares well with the ϕ' obtained by Mendo (1984) in Peruvian waters and Morales-Nin (1988) in Ecuadorian waters (Table 2). This suggests that *S. japonicus* found in the two areas belong to the same stock.

LENGTH-WEIGHT RELATIONSHIP

Estimates of the parameters of the length-weight relationship of *S. japonicus* are given in Table 3. Yearly variability in the value of the intercept a was relatively high (C.V.=45%). Conversely, yearly variability of the power **b** was low (C.V.=4%), ranging between 3.168 and 3.569. The 95% confidence intervals for the mean value of b are 3.242 and 3.460. Because this interval does not include b=3, a positive allometric length-weight relationship is considered for *S. japonicus* in the Gulf of Guayaquil, i.e., fish tend to become fatter as they grow larger. Therefore, the model of allometric growth was used for calculation of the condition factor ($c.f.=W.100/FL^{3.351}$).

Overall, the mean value of b=3.351 estimated in this work is significantly higher than the values of b=2.956 and b=3.020 reported for the same area in 1982 and 1983, respectively and significantly lower than the value of b=3.627 reported for 1984 by Menz and Pizarro (1988) (Table 4). The former may be associated with the occurrence of a very strong El Niño warm event during 1982 and 1983 that severely affected the availability of food for pelagic fish in the southeastern Pacific region, forcing some species to undergo exhausting migrations in search for food.

Conversely, the mean value of b=3.351 is not significantly different from the value b=3.423 reported in Chile by Aguyao et al. (1982) (Table 4).

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E. CUCALÓN-ZENCK *is from Oceanografia y Pesca Consultores (Fisheries and Oceanography Consulting)PO Box 09-01-4382, Guayaquil, Ecuador. Email: ecucalon@gu.pro.ec*

NTAFP News

International Conference on Risk Analysis in Aquatic Animal Health

The Office International des Epizooties (OIE) has announced the organization of an international conference on Risk Analysis in Aquatic Animal Health, 8-10 February 2000 in Paris. Keynote presentations will be made by speakers from international agencies, national government departments, academic institutions and the aquatic animal trade. For further information please contact: Dr. K. Sugiura, Office International des Epizooties, 12 rue de Prony, 751017 Paris, France;, Tel. 33 (0) 1 44.15.18.88; Fax 33 (0) 1 42.67.09.87. Email: K.Sugiura@oie.int or oie@oie.int

Fifth Indian Fisheries Forum

The Indian Branch of the Asian Fisheries Society, in collaboration with Association of Aquaculturists, is organizing the Fifth Indian Fisheries Forum during 23-26 November 1999 in Bhubaneswar, India. All topics related to fisheries will be covered in simultaneous scientific sessions. The highlight of the Forum will be a symposium on Asian Aquaculture in the Next Millenium to be held on 25 November 1999. Leading scientists and fisheries administrators from several Asian countries will present theme papers. For more details and registration, please contact: Dr. S. Ayyappan, Director, Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneswar 751 002, India;, Tel. (91-674) 463-421; 463-430; Fax (91-674) 463-407; 404-222. Email: cifa@mx400.nicgw.nic.in

Aquaculture Economics and Marketing Conference

The Debrecen Agricultural University, Fish Culture Research Institute, Ministry of Agriculture and Regional Development and the Hungary Collective Agricultural Marketing Centre of Hungary are jointly organizing a conference on Aquaculture Economics and Marketing from 30 August to 1 September 1999 at the Debrecen Agricultural University, Debrecen, Hungary. The organizers are inviting oral and poster presentations in the areas of: (i) business administration and management; (ii) the role of fisheries and aquaculture in the national economy; (iii) quality aspects and quality assurance; (iv) marketing aspects; (v) socioeconomics in aquaculture and fisheries; (vi) resource-use planning; (vii) legal aspects; and (viii) research management and extension in aquaculture. The language of the conference will be English. Registration fee is US$450 (for students US$250). For additional information, contact: Ms. Agnes Varadi, organizer, Fish Culture Research Institute, 5541 Szarvas, Pf. 47, Hungary; Fax: +36 66 312 142. Email: varadi@haki.hu