ON THE SEASONAL GROWTH, MONTHLY RECRUITMENT AND MONTHLY BIOMASS OF PERUVIAN ANCHOVETA (*Engraulis ringens*) FROM 1961 TO 1979[*]

by

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Resumen

Se han examinado en detalle datos de longitud-captura mensual de anchoveta peruana (*Engraulis ringens*) correspondientes a la region Norte, usando los programas de computadora ELEFAN I y III (Electronic LEngth Frequency ANalysis). ELEFAN I proporcionó para cada uno de los años, desde 1961 a 1979, valores similares de L_∞ y K de la ecuación de crecimiento de Von Bertalanffy. Se muestra que ocurren oscilaciones estacionales en el crecimiento, los cuales son cuantificados.

El programa ELEFAN III, que permite la aplicación de diferentes formas del análisis de población virtual en base a datos de longitud-captura, fue empleado para obtener series de tiempo, sobre una base mensual, de los siguientes parámetros: reclutamiento (R), stock desovante (S) y biomasa total (B). También se presentan y discuten series de tiempo de capturas mensuales (C) y de valores derivados ($\log_e$ (R/S) y F = C/B).

INTRODUCTION

For about 10 years (1962–1971), the Peruvian anchoveta (*Engraulis ringens*, Jenyns [Fam: Engraulidae]) supported the largest single-species fishery in the world, with annual catches in excess of 12 million tonnes. Present catches are lower, but still make this species a very important aquatic resource (see contributions in Glantz and Thompson, 1981). The anchoveta has been much studied, and indeed, most methods available for assessing exploited fish stocks have been applied to the anchoveta, often by the very scientists who developed these methods (Boerema et al., 1967; Schaefer, 1967; Gulland, 1968; IMARPE, 1970, 1972, 1973, 1974, 1977a).

The present paper continues this tradition in that it reports on the application to the anchoveta of a newly developed set of methods for the investigation of exploited fish stocks. The set of methods are incorporated in the ELEFAN (Electronic LEngth Frequency ANalysis) programs developed at ICLARM[*] which are applied to catch-at-length data from the Northern Region of Peru and covering the years 1961 to 1979.

Of the three available, the two ELEFAN programs used were:

- ELEFAN I (Pauly and David, 1981; Pauly et al., 1980); this program is used for the extraction of growth parameters from length-frequency (L/F) or catch-at-length (C/L) data, using an algorithm which allows for seasonal growth oscillations to be considered and which provides results that are fully reproducible.

- ELEFAN III (Pope et al., MS, cited in Pauly, 1982); this program was used to run two types of length-structured virtual population analysis (VPA) on catch-at- length data, and to obtain estimates of recruitment, standing stock and fishing mortality on a monthly basis.

The analyses performed and the conclusion reached here are, for reasons to be discussed further below, quite preliminary. This paper should be read with emphasis on the methodology used, rather than on the numerical values of the results obtained.

MATERIAL AND METHODS

Raw data

The data used for all analyses presented here originally consisted of monthly length- frequency data collected from March 1961 to December 1979 by staff of the Instituto del Mar del Perú (IMARPE) in the ports of Chicama, Chimbote, Samanco and Casma (of these Chimbote accounts for more than 80% of anchoveta landings in the Northern Region). The data analyzed here thus pertain to the northern stock of anchoveta (see IMARPE, 1970 for comments on the status of anchoveta stocks off the Peruvian-Chilean coast).

The sampling procedures for length-frequency samples generally followed those given in Saetersdal and Valdivia (1964), who presented data suggesting that for the stretch of coastline ranging from the Northern to the Central Regions, within port variability of the length-frequency samples was less than variability due to different sampling periods. Monthly samples representative of the northern stock as a whole were obtained by pooling daily samples representing more than 30% of the landings, and most of the fishing areas covered by the fleet. Generally, one single sample was taken from each vessel sampled; the sample consisted of the contents of a two-litre container, of which all anchoveta were measured and weighed. The monthly samples representative of the monthly catches were then raised to the catch.

* The first version of ELEFAN III was written by J.G. Pope at Lowestoft, England.

During periods when the commercial fishery was closed, length-frequency data were obtained from 1972 on by sampling during “EUREKA Surveys”, and other scientific surveys and cruises. Here, the samples (taken after each haul) were raised to the total catch made during the survey or cruise (see IMARPE, 1972, 1974 for brief accounts of the EUREKA and other surveys and cruises).

The data used all refer to total length, and are grouped in 0.5 cm classes. For the analysis of growth, the data were regrouped into 1 cm classes to obtain a number of length classes of about 20 or less, which is optimum for analysis with ELEFAN I (Pauly et al., 1980).

The full data set used here extended to the period before 1961 and beyond 1979 will be published later, along with an analysis more detailed than that presented here.

Growth

The analysis of length-frequency and catch-at-length data using ELEFAN I is based on the following assumptions (adapted from Pauly and David, 1981):

- the samples used represent the population investigated,

- the seasonally oscillating version of the von Bertalanffy Growth Function (VBGF) describes the average growth of the fish,

- all fish in the samples have the same length at the same age and therefore differences in length can be attributed to differences in age.

Another assumption in Pauly and David (1981), namely “that the growth patterns are the same from year to year” need not apply here as the estimation of growth parameters was performed separately for each year. The last of the three assumptions above certainly does not apply as anchoveta of different sizes can very well be expected to have the same age. The anchoveta, however, is not a long-lived fish, and, as will be shown below, the bulk of a cohort goes through the exploited phase within less than two years, with the result that fish hatched during say, a given month remain identifiable as a group through- out most of their exploited life span (see Saetersdal and Valdivia, 1964 and Fig. 1).

Put briefly, the ELEFAN I program does the following (adapted from Pauly and Ingles, 1981):

- restructures the length-frequency samples that have been entered such that “peaks” are attributed “positive points”, and the “troughs” separating peaks “negative points”,

- calculates from the positive points of the peaks of all samples entered a sum named “available sum of peaks” (ASP, analogous to the total variance of parametric methods),

- traces a series of growth curves starting from the bases of the peaks, and projects these curves backward and forward in time such as to hit the other samples in the data set and recording all “points” (positive and negative) “hit” by a curve,

- identifies the curve and hence, the growth parameters - which, by passing through most peaks and avoiding most troughs, best “explains” the peaks in the sample set. This curve will have scored the highest number of points, whose sum is called on the “explained sum of peaks” (ESP, analogous to the explained variance of parametric methods).

Given the validity of the assumptions presented above, ELEFAN I can be used to obtain growth parameters that are completely objective, i.e., in which no assumptions as to the age composition of the catch have been incorporated prior to analysis (Pauly and David, 1981).

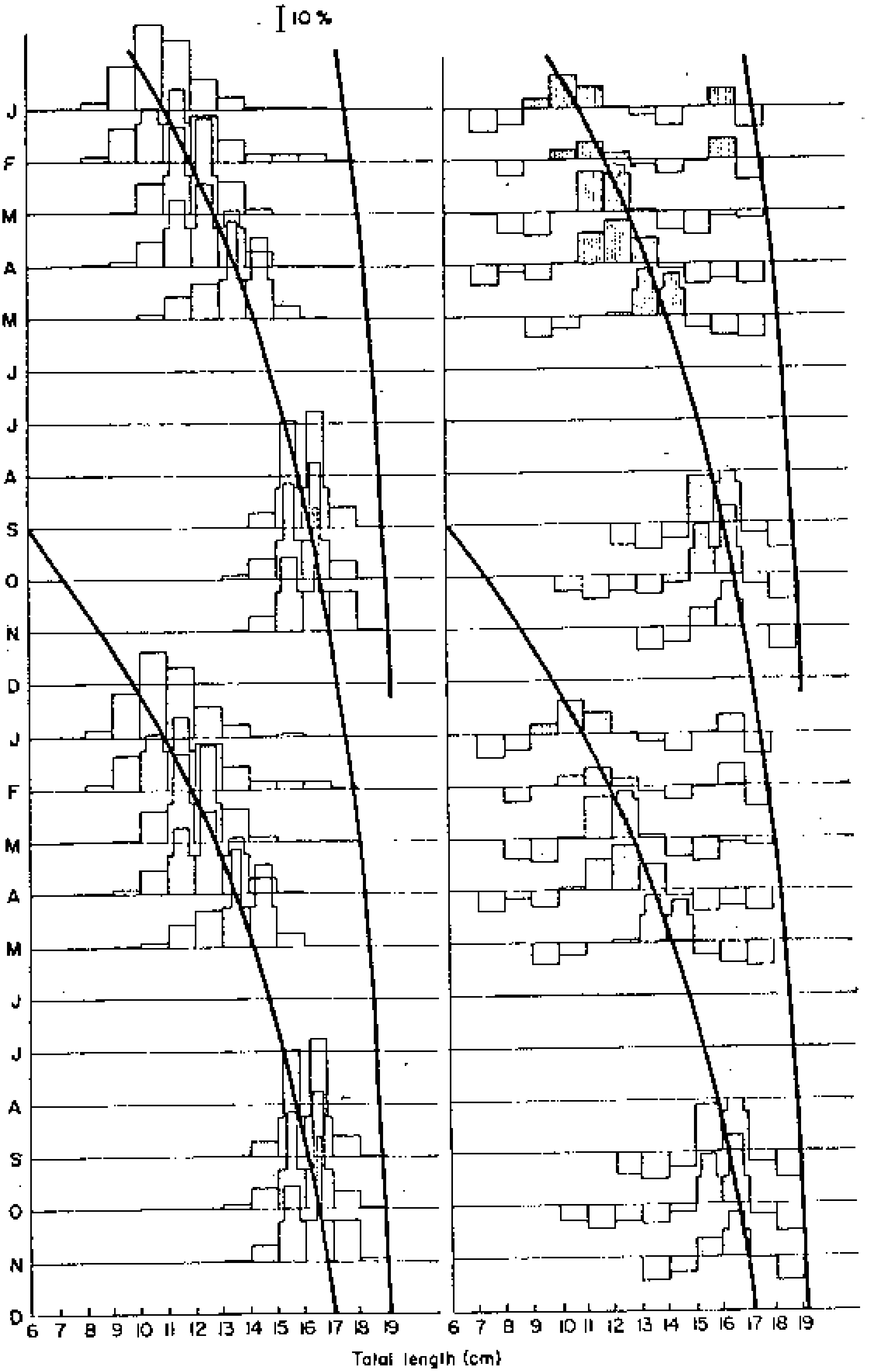

Fig. 1. (Left) Catch-at-length data for anchoveta, fitted with a growth curve using ELEFAN I; note “doubling up” of 1970 data to allow for a longer growth curve to be drawn.

(Right) Restructured length-frequency data as used internally by ELEFAN I; note that, through the restructuring process, peaks have become positive “points” (shaded bars) while the troughs separating peaks have become negative “points” (open bars).

The seasonally oscillating version of the VBGF used here has the form

$$L_t = L_\infty \left(1-\exp\left(-\left[\left[K(t-t_0)\right] + \left[\frac{KC}{2\pi} \sin 2\pi \ (t-t_s)\right]\right]\right)\right) \qquad \ldots 1$$

where:

L_t is the length at age t,

L_∞ the asymptotic length,

K a growth constant,

t_o the “age” at which length is zero if the fish always grew according to the equation,

C is a dimensionless constant expressing the intensity of the growth oscillations,

and t_s is the time (with respect to t=0) at the beginning of a sinusoidal growth oscillation of period one year (Pauly and Gaschütz, 1979; Gaschütz et al., 1980).

In ELEFAN I, the estimation of t_s is replaced by the estimation of a Winter Point (WP), defined as

$$t_s + 0.5 = WP \qquad \ldots 2$$

which expresses (as a fraction of the year) the time during which growth is slowest. It should be mentioned here that ELEFAN I, being based on length-frequency data (rather than length-at-age data) does not allow for the estimation of t_o, hence of absolute ages; all “ages” used internally by the program are relative ages, expressed in relation to an arbitrary birthdate (the 1st of January).

ELEFAN I was applied to the available data for the years 1969 to 1979, yielding 19 independent estimates of growth parameters.

Virtual Population Analysis

The ELEFAN III program, in its latest version (Pope, et al., MS) consists of 4 main routines:

- a routine to convert length-frequency data into catch-at-length data (not used here, as IMARPE data had already been converted),
- a routine to run a conventional age-structured VPA (here termed VPA I), as discussed, e.g., in Pope (1972),
- a routine to run a VPA-version of Jones' (1979, 1981) length-cohort analysis (here termed VPA II, see below), and
- a routine to run an age-structured VPA on catch-at-length data arranged such that they produce the functional equivalents of cohorts (here termed VPA III, see below).

VPA I is based on the equation

$$\frac{N_{i+1}}{C_i} = \frac{Z_i \cdot \exp - Z_i}{F_i\ (1-\exp-Z_i)} \qquad \ldots 3$$

where N_i is the population (in number) at the beginning of time period i, while C_i and F_i are the catch and the fishing mortality during that same time period i. Usually equation (3) is solved (iteratively) backwards, starting from a "terminal population" (N_t) estimated from

$$N_t = \frac{C_t \cdot Z_t}{F_t\ (1-\exp-Z_t)} \qquad \ldots 4$$

where F_t is the (assumed) terminal fishing mortality and C_t the terminal catch, while M is the natural mortality which is generally assumed constant throughout (Pope, 1972).

Generalizing equation (3) to any time interval (°) gives

$$\frac{N_i + \Delta t}{C_i} = \frac{Z_i \cdot \exp\ (Z_i \cdot \Delta t)}{F_i\ (1-\exp-Z_i \cdot \Delta t)} \qquad \ldots 5$$

This equation is a functional equivalent of Jones (1979, 1981) equation for length cohort analysis and can be used to run a VPA on catch-at-length data starting from

$$N_t = C_t \cdot Z_t/F_t \qquad \ldots 6$$

and estimating ° from

$$\Delta t = \frac{1}{K} \cdot \log_e \left\{ \frac{L_\infty - L_1}{L_\infty - L_2} \right\} \qquad \ldots 7$$

i.e., by calculating using the VBGF, the time needed to grow from the lower (L_1) to the upper (L_2) limit of a length class (see Jones, 1981). Equation (5) is used here, instead of the original length-cohort analysis proposed by Jones (1979, 1981) because as shown by Pauly (in press) the VPA version of Jones' method produces results which are insensitive to the width of the length classes into which the catch data are grouped; Pope et al. (MS) and Pauly (in press) give more details on this method.

It must be mentioned, however, that the method does not provide estimates of standing stock and fishing mortality pertaining to a given cohort (as does VPA I); rather the method provides estimates of the population of fish and the fishing mortalities that must have existed for the recorded catches to have been generated (Jones 1981). The method is therefore at its best when catch data from longer time periods are grouped such as to simulate equilibrium conditions.

For this paper, we have grouped the available monthly catch data into years, and thus report estimates of annual recruitment, standing stock and fishing mortality.

VPA III is a version of VPA I performed on “cohorts” obtained by superimposing growth curves, drawn at monthly intervals, onto a set of catch-at-length data, the catch pertaining to each “cohort” and month being simply that part (obtained by addition and interpolation) of a monthly catch contained between two growth curves (see Fig. 2).

For such cohorts to consist of fish recruited at the same time, the growth curves used for “slicing up” a cohort must be obviously as close to the true growth curve of that cohort as possible, which among other things makes it imperative that a seasonally oscillating curve be used since, as shown in Pauly and Ingles (1981) and Pauly (1982), virtually all fish species display seasonally oscillating growth.

In reality, not all fish of a given cohort have the same growth parameters, and it can be expected that some fish will “leave their cohort” because they grow either faster or slower than predicted by the mean growth curve of their cohort. Such differences in growth rate should here have the effect of somewhat smoothing month to month variations in the estimates of fishing mortality and derived parameters.

The VPA III routines of ELEFAN III were applied to the available catch-at-length data using the growth parameters given in Table 1. The small year-to-year differences in the values of the growth parameters caused a slight overlap of some “cohorts” (i.e., some of the catch data were used twice), and small gaps (i.e., some of the catch data were not included in any cohort.) This source of error could have been avoided by using the same growth parameters throughout. This, however, would have caused misidentification of some cohorts.

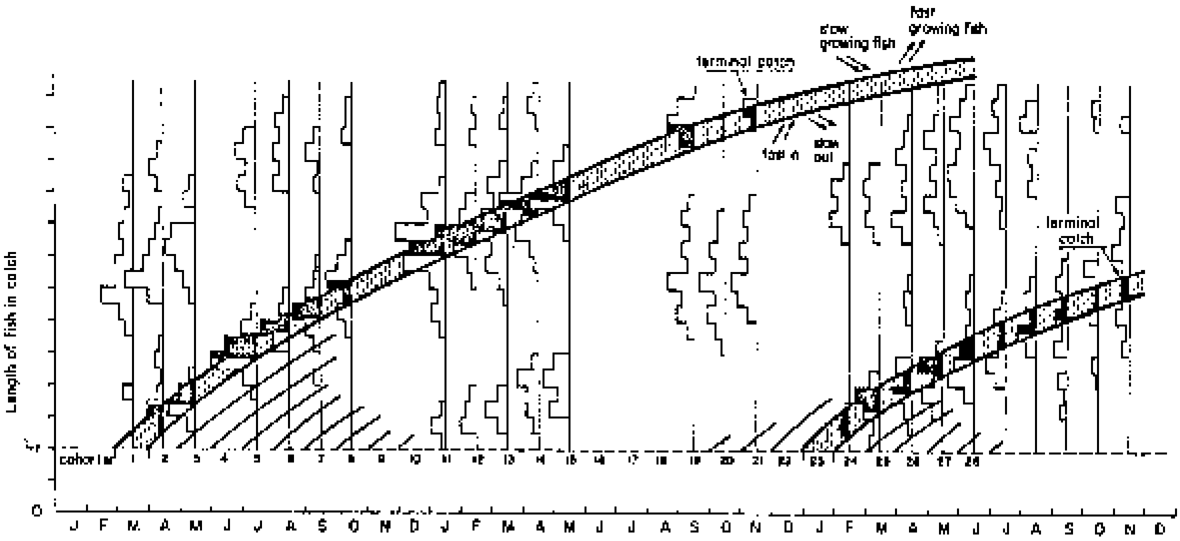

Fig. 2. Schematic representation (not to scale) of VPA III as implemented in ELEFAN III. Two “cohorts” (#1 and 23) are shown; they are defined by the growth parameters of the growth curves on their upper and lower boundaries, and by that part of the catch (black histograms) comprised between these boundaries. The terminal catches are shown. Note (partial) compensation of fish leaving a “cohort” (due to slower or faster growth) by fish from neighbouring cohorts. Length at recruitment (L_r) is defined by smallest fish in catch.

Table 1: Growth parameters of Peruvian anchoveta (*Engraulis ringens*, northern stock) as estimated by means of the ELEFAN I computer program.

Year	L_∞ (cm)	K (per year)	WP[a]	C[a]	ESP/ASP
1961	19.65	1.26	(0.6)	(0.2)	0.572
1962	20.75	1.16	0.8	0.35	0.513
1963	18.95	1.39	0.8	0.3	0.439
1964	20.70	1.22	0.6	0.23	0.588
1965	20.75	1.21	0.6	0.4	0.503
1966	20.75	1.30	0.65	(0.3)	0.475
1967	20.05	1.36	0.9	0.3	0.655
1968	20.95	1.205	0.96	0.32	0.655
1969	20.95	1.19	0.6	0.23	0.570
1970	19.55	1.39	0.8	0.3	0.832
1971	20.75	1.30	(0.75)	(0.3)	0.532
1972	20.70	1.27	0.7	0.3	0.421
1973	20.95	1.20	0.5	0.3	0.598
1974	21.85	1.20	0.5	0.2	0.504
1975	21.25	1.16	0.5	0.2	0.581
1976	21.25	1.31	0.85	0.3	0.420
1977	21.05	1.31	0.8	0.3	0.519
1978	20.75	1.2	0.6	0.4	0.787
1979	20.75	1.215	0.82	(0.3)	0.458
$\bar{x}$	20.65	1.26	0.70	0.30	-
s.d.	0.681	0.073	0.147	0.061	-
C.V. (in %)	3	6	21	20	-
95% confidence interval	±0.31	±0.033	±0.070	±0.031	-

[a] values in brackets are set values; they were not used for the computation of means or confidence intervals.

Preliminary computations suggest that the errors in the recruitment and standing stock estimates are of about ±15%, which is quite acceptable given the uncertainties involved in such important parameters as natural mortality and terminal fishing mortality (see below).

A value of M=1.2 (annual basis) was used throughout, for both VPA II and VPA III. This value has been used previously by several authors (e.g. Ricker, 1975, p. 197), and was obtained as the intercept of a plot of Z (obtained from catch curves) on effort (T. Burd, pers. comm. in Schaefer, 1967).

A terminal fishing mortality F_t=1.2, corresponding with M=1.2 to an exploitation rate (E=F/(F+M) of 0.5 was used to estimate terminal populations for both VPA II (using Equation 6) and VPA III (using Equation 4). Since E=0.5, as will be shown below, was reached in the mid-60's, the terminal populations have been underestimated in the earlier years, and overestimated in the later years.

Size at recruitment was defined as 4 cm, i.e., slightly less than the 5 cm value used by other authors. It must be considered that, in any case, true catches of “peladilla” (small anchoveta) are underestimated because the fish often disintegrate before processing.

The mean size at first maturity (i.e., the size distinguishing adults from juveniles) used here was a constant set at 11 cm. This is slightly lower than the 12 cm figure suggested by other authors (Saetersdal and Valdivia, 1964; Murphy, 1972). This size was chosen to account for cases (during El Niño events) where fish reach maturity at much reduced sizes (Tsukayama and Alvarez, 1981).

Biomasses were estimated by multiplication of computed population size (by length) with fish weights, the fish weights being estimated from

$$W=a\ .\ L^{b}\ \ldots \qquad 8$$

Values of a=0.0065 and b=3 were used throughout, with length expressed in centimetres and W in grams. At this stage of our analysis, we made no efforts to account for within and between years variations of the length/weight relationships, although we are aware that such variations occur (IMARPE, 1976, 1977a, 1977b, 1980, 1981, 1982), and may cause under- or over-estimates of standing stock.

All computer-based analyses were performed on a Radio Shack TRS 80 Model III micro-computer.

RESULTS

Growth

Table 1 gives 19 estimates of the values of the growth parameters L, k, C and WP for the period 1961 to 1979. As might be seen, there was no trend over time in any of the parameters and it can therefore be stated that the parameters describing the growth in length of the northern stock of the Peruvian anchoveta have been more or less constant from the period 1961 to 1979, despite large changes in biomass (this does not preclude changes in the growth in weight, see above).

The mean value of C=0.30 suggests that the growth of anchoveta oscillates seasonally in sinusoidal fashion, and that it is, during the warmest summer month, 30% higher than it would be if no oscillations occurred. Conversely, the growth of anchoveta is reduced in winter, down to a 30% reduction during the coldest month; “winter” as perceived by the anchoveta occurs at WP=0.70 ± 0.07, corresponding to the 12th of September (± 26 days). The temperature data in Zuta and Urquizo (1972) show that sea surface temperatures off Peru oscillate in sinusoidal fashion, with most common values for minima and maxima occurring in September and March, respectively.

The range of the oscillation of mean monthly temperature, moreover, is 3 to 6°C; these values correspond well to the mean value of C (which expresses the intensity of the growth oscillations) reported here (Fig. 3).

Two important points must be borne in mind when considering these results:

- the values of C and WP were extracted from length-frequency data, yet match very well the values that would have been predicted on the basis of the temperature regime off Peru alone and

- the oscillations reported here are generally too faint to be perceived, let alone quantified using standard methods (i.e., eye-fitting) for the analysis of length-frequency data.

VPA II

Table 2 summarizes the results obtained using VPA II (Table 3 gives an example, pertaining to 1968, of the output obtained from ELEFAN III).

VPA III

The estimates of recruitment (R), adult stock (S), values of $\log_e$ (R/S), the catches, total biomass and estimates of fishing mortality are presented as monthly values for the period 1961 to 1979 in Figs. 4 to 9.

The values of $\log_e$ (R/S) in Fig. 6 are in fact values of $\log_e$ (R_i/S_{i-1}), i.e., the recruitment of a given month was plotted against the adult biomass of the preceding month. Fig. 14 in Saetersdal and Valdivia (1964) suggests that 4 cm fishes are generally between 1 and 2 months old.

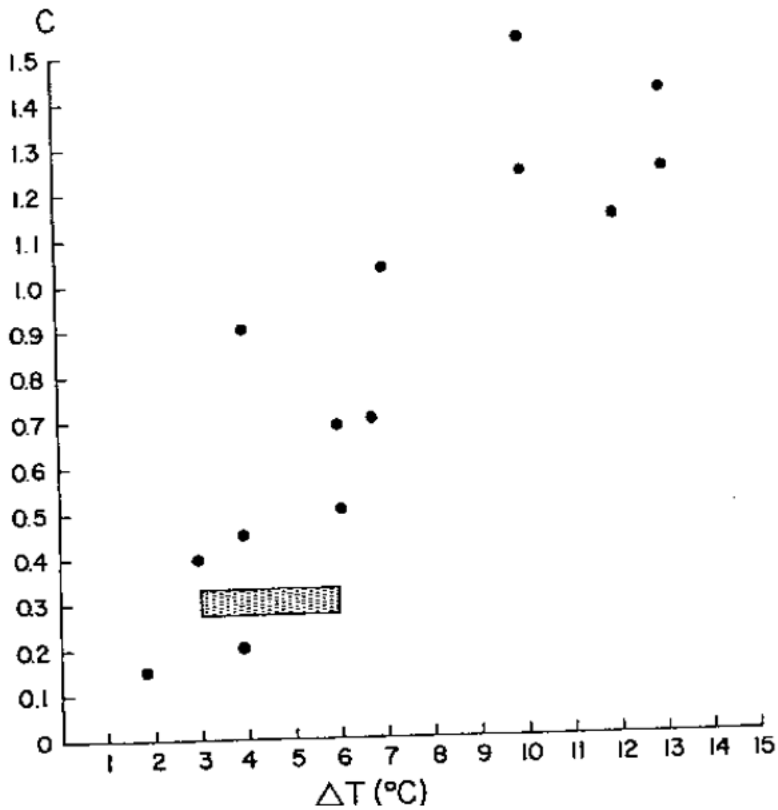

Fig. 3.Values of C (expressing the intensity of seasonal growth oscillations) plotted against ° T (expressing the difference between warmest and coldest mean monthly water temperature) in a number of tropical and temperate fishes. The shaded area, referring to the anchoveta, is based on the C values in Table 1 and range of ° T values in Zuta and Urquizo (1972). Note that the seasonal oscillations in the growth of anchoveta conform to the general pattern established for other fishes by Pauly and Ingles (1981).

Table 2: Results of VPA II for the years 1961[a] to 1979.

Year	**Recruitment**[b]	**Catch**[c]	$\bar{e}$[d]	$\bar{F}$[e]	$\bar{B}$[c, f]
1960	212	-	-	-	-
1961	317	1314	0.39	0.77	1713
1962	295	2194	0.39	0.75	2908
1963	509	1908	0.40	0.81	2365
1964	353	3429	0.47	1.07	3197
1965	434	2290	0.46	1.01	2258
1966	479	2903	0.52	1.33	2177
1967	579	3837	0.33	0.58	6581
1968	547	4351	0.36	0.68	6418
1969	626	3293	0.51	1.26	2616
1970	483	4028	0.46	1.03	3909
1971	127	3289	0.49	1.14	2887
1972	359	910	0.38	0.72	1264
1973	159	321	0.48	1.11	289
1974	114	744	0.35	0.64	1157
1975	132	852	0.34	0.61	1391
1976	22.5	566	0.61	1.88	302
1977	8.72	135	0.51	1.24	109
1978	61.6	425	0.51	1.26	336
1979	-	321	0.46	1.00	320

[a] The January 1962 and February 1962 catches were added to the 1961 catch (March to December) to obtain 1961 figures comparable to those of the other years.

[b] The catch of a given year was used to infer recruitment the preceding year; this is an approximation (see text); recruitment refers to number of 4 cm fish (x 10^9).

[c] In tonnes ($x10^3$)

[d] Obtained from E=number of fish caught/number of fish dying of all causes; latter number is approximated by the recruitment itself, since all fish recruited finally die.

[e] Obtained as F=(M/(1-E))-M.

[f] Obtained from $\bar{B}$ =catch in weight/mean fishing mortality.

Table 3 : Results of VPA II for the year 1968 (see Table 2).

<<<<< VPA 2 RESULTS FOR ENGRAULIS RINGENS 1968 >>>>>			
LENGTH	**CATCHES**	**POPULATION**	**FISH. MORTALITY**
19–19.5	3	6	1.2
18.5–19	17	25.768	7.37504
18–18.5	106	143.361	10.9724
17.5–18	1056	1274.2	16.9331
17–17.5	4349	8008.53	13.5436
16.5–17	11183	18433	10.8091
16–16.5	19061	40308.8	8.12607
15.5–16	36190	81861.2	8.09872
15–15.5	36383	126845	5.07618
14.5–15	34147	172461	3.57291
14–14.5	12637	198366	1.14295
13.5–14	5840	218118	.503711
13–13.5	2809	235119	.237521
12.5–13	4008	253521	.334135
12–12.5	3614	271744	.29685
11.5–12	4647	291220	.376049
11–11.5	4272	310547	.340511
10.5–11	3933	329733	.309429
10–10.5	2788	347927	.217158
9.5–10	3135	366598	.24216
9–9.5	2372	384620	.18188
8.5–9	2204	402564	.168023
8–8.5	1381	419754	.104829
7.5–8	1007	436612	.0762341
7–7.5	492	452980	.0371878
6.5–7	186	469052	.0140503
6–6.5	47	484987	3.54992E–03
5.5–6	5	500878	3.77701E–04
5–5.5	17	516780	1.28429E–03
4.5–5	8	532671	6.04442E–04
4–4.5	4	548556	3.02256E–04
TOTAL	CATCH = 197901	MEAN E = .360767	MEAN F = .677251

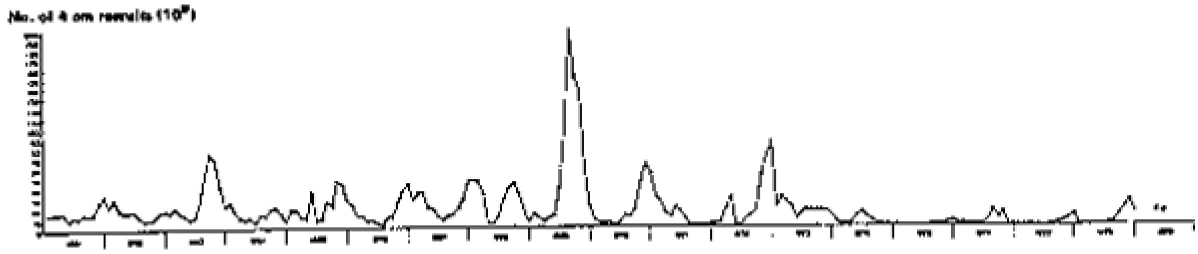

Fig. 4. Monthly recruitment to the northern stock of Peruvian anchoveta, 1961 to 1978. Overall, this time-series matches closely the sequence of events given by previous authors, particularly Cushing (1981).

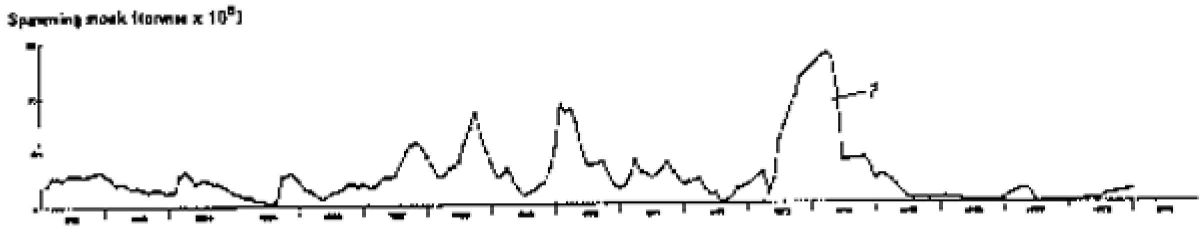

Fig. 5. Monthly estimates of adult biomass (defined as fish>11 cm, see text). Overall, this series matches most of the estimates in previous works, notably IMARPE, 1970, 1972, 1973 and 1974 and Cushing, 1981. Differences may be explained by large differences in approaches used. The enormous increase in 1973–1974 may be an artefact due to the use of unrealistic values of M (see text).

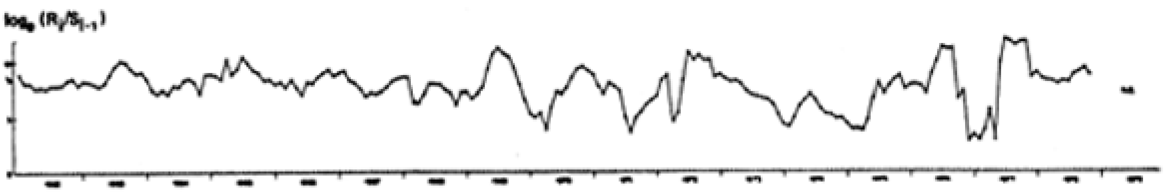

Fig. 6. Time series of $\log_e (R_i S_{i-l})$. This index would be a direct expression of egg and larval survival if adult fish spawned every month an amount of eggs proportional to their biomass. As used here, it expresses both "non-spawning" <u>and</u> survival of pre-recruits. Nevertheless, a close association between this index and El Niño events will be noted.

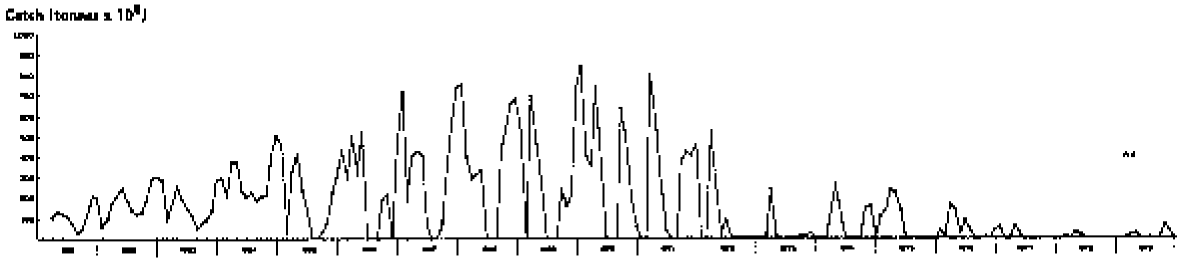

Fig. 7. Monthly catch of anchoveta, northern stock, 1961 to 1979. Zero catches represent periods of closure, not of Zero availability of fish.

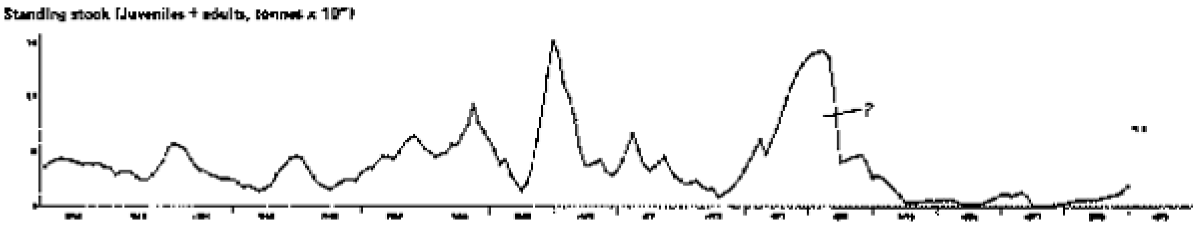

Fig. 8. Time series of total anchoveta biomass (adults and juveniles, but excluding fish < 4 cm), northern stock. Major sequence of events as expressed here match earlier accounts, except for enormous increases in 1973–1974 which may be an artefact due to the use of unrealistic values of M (see text).

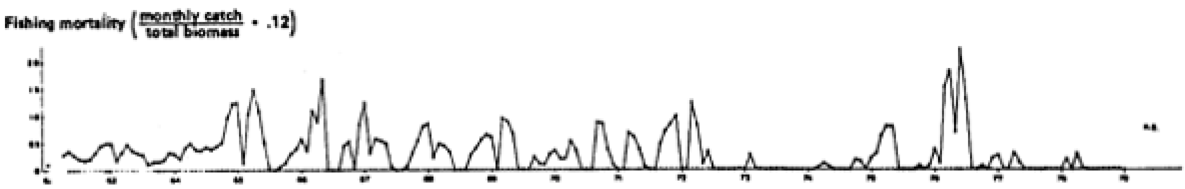

Fig. 9. Estimated values of fishing mortality (F) obtained by dividing catches in Fig. 7 by biomasses in Fig. 8. Obviously, errors in the biomass estimates will be reflected in the values of F which, therefore, should be considered as tentative.

DISCUSSION

The following parameter values are now available on the growth of *Engraulis ringens*:

L (cm)	K (per year)	Source
15	1.7	Saetersdal and Valdivia (1964)
16.8	1.4	Chirinos de Vildoso and Chumán (MS)
18.5	1.1	Tsukayama and Zuzunaga (MS)
19.0	1.11	Simpson and Buzeta (1967)
20.65	1.26	this study (Table 1)

Of the parameter values obtained previously, those of Tsukayama and Zuzunaga (MS) and those of Simpson and Buzeta (1967) appear most reasonable, especially in view of the fact that old *E. ringens* may reach a length of 17–18 cm. We believe the discrepancy between our estimates and the two earlier sets is due to our having considered seasonal growth oscillations; thus what here appears as the acceleration (due to a summer spurt) of an otherwise steady growth presumably has been interpreted as a rapid growth toward a smaller maximum size.

In any case, our results are similar to those of other authors in that they imply that anchoveta, once recruited, may stay about two years in the fishery, notwithstanding the return of a fish tagged up to 5 years previously (Cushing 1981).

The most interesting part of the growth study presented here is, we believe, the demonstration and quantification of growth oscillations which so closely fit the general pattern derived from the study of a number of other fish species (Fig. 3).

This is encouraging because it implies that the anchoveta is not such a special fish after all, and that parameter values(e. g. , for use in simulation modelling) detained from stocks similar to the Peruvian anchoveta may be used.

The application of VPA II does not seem to be useful in the case of a short-lived fish such as the anchoveta, where the stock size may fluctuate violently within periods of a few months. Inherent to the VPA II method is, it is recalled, the need to group data over a period of time when conditions are somewhat constant, which was hardly ever the case off Peru. Based on the present experience, it seems now that it would be most appropriate to limit the application of this method to stocks of long-lived animals in which recruitment fluctuations cause only ripples in the size of the accumulated stock.

VPA III, on the other hand, seems eminently suited to study the dynamics of anchoveta as reasonable estimates of recruitment, biomass, fishing mortality and other quantities could be derived with an extremely limited amount of data beyond the catch data themselves. However, the number presented here could all be rendered more accurate by considering the following:

(1) the assumption of constant mortality (M=1.2) used here certainly does not apply, and subsequent applications of VPA III to the anchoveta stock should take this into account, e. g., by expressing natural mortality as a function of the biomass of their major predators (guano birds, certain fishes). This should help bring the standing stock estimates for 1973–1974 (Figs. 5 and 8) down to more realistic values, among other things;

(2) the terminal fishing mortalities used to initiate the VPA 's should not be constant either, but rather should reflect the increase in F noted, e.g., in this study;

(3) the conversion of fish numbers to biomass should take into account the changes in condition factor reported for the anchoveta;

(4) the catch data from the "northern stock" should be pooled with at least those from the "central stock" to account for the large exchanges known to occur between these stocks;

(5) the time series should be if possible extended back in time to obtain more data reflective of a situation when between-month variability in stock size was reduced, and forward in time to include more data from that period when the anchoveta was supplanted by other pelagics.

Given these adjustments and improvements, we believe that the method presented here could lead to significant insights into the mechanisms which determine anchoveta recruitment. The large number of stock and recruitment values obtained will allow the testing of a large number of variables (biotic and abiotic) for their effect on $\log_e$ (R/S), as suggested by IMARPE (1973) and performed (with only 2 variables) by Csirke (1980). However, as noted by Bakun et al. (1982) "there is always an extremely limited number of data points available (one per year). Thus, the number of explanatory variables must be reduced to a minimum".

The VPA III approach presented here overcomes this constraint, as 12 values of stock size and recruitment are generated per year. Thus, we have here 203 data points enough to test a large number of variables for their effect on $\log_e$ (R/S) (including dummy variable (s) for the "spawning season" itself).

We believe that it is the last mentioned aspect of the methodology proposed here which has the greatest potential, because having a large number of relatively independent data points offers the real possibility of identifying and quantifying factors with crucial impact on recruitment. Such factors, once identified, will certainly allow better yield predictions to be made.

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