EDITORIAL

This edition of *Fishbyte*-in-*Naga* presents the mix of concept or methods-orientated and species- or location-specific studies which I strive to maintain (when I am not on vacation - sorry about the last issue!).

Moreover, we have some real highlights: the paper of Mendoza et al., which represents the first application of what I called "VPA III" by a group outside of ICLARM, Temming's elegant demonstration of the usefulness of the generalized VBGF for estimating food consumption in fishes, Arias-Gonzalez et al.'s identification of an important factor affecting coral reef yield predictions and more.

And then there is FiSAT and FishBase, two major pieces of software developed at ICLARM in the last years, and which some colleagues thought would never come out ... all in all an exciting issue.

Finally, one bit of news on my own behalf: from October 1994 on, I'll be leading a double life, and share my time between the Fisheries Centre, University of British Columbia, Vancouver, Canada, where I'll be a Professor (a new experience for me!) and ICLARM, where my new position will be that of Principal Science Adviser. This will enable me to have the best of both worlds: winter rains in Vancouver, and monsoon rains in Manila.

Correspondence meant to reach me as Fishbyte editor and NTFS coordinator, or any other capacity in October/November or from January to March should therefore be sent to the Fisheries Centre, The University of British Columbia, 2204 Main Mall, Vancouver, B.C. Canada V6T 1Z4, Fax: (604) 822-8934, Tel: (604) 822-2731, otherwise to ICLARM. ***D. Pauly***

VPA Estimates of Fishing Mortality and Exploited Biomass from *Sardinella aurita* Catch-at-Length Data in Eastern Venezuela

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Abstract

In this study, length-frequency data on Spanish sardine (*Sardinella aurita*) from northeastern Venezuela were analyzed for the period 1967-1989. Average growth parameters for the von Bertalanffy equation were estimated as L_∞ = 26.6 cm (TL) and K = 1.26 year^{-1}. The number of recruits to the fishing area, estimated from length-structured Virtual Population Analysis, varied from <10^8 in the late 1960s to >10^9 at the end of the 1980s. Exploited biomass estimates for the same period varied from less than 20,000 t in the first years to more than 100,000 t in 1989. Both recruitment and exploited biomass showed different seasonal patterns between 1976-1983 and 1984-1988. Despite some uncertainty regarding these estimates, it is considered that major population tendencies are adequately represented by this analysis.

Introduction

Sardinella aurita represents the most important single species fishery in Venezuelan waters. According to official statistics, around 53,000 t were landed in 1989, after a record production of 80,000 t in 1988. This small-scale fishery occurs exclusively in the northeastern Venezuelan region, where exploitation is carried out by beach and purse seines in areas close to the littoral zone (Fig. 1).

Several aspects of the biology and exploitation of this species have been studied in this area. Among these we may mention the work of Griffiths and Simpson (1967), Etchevers (1974), Trujillo (1977, 1980) and Anon. (1990) on exploitation and evolution of catch and effort statistics, and the work of Simpson and González (1967), López (1972) and Anon. (1984) on the reproduction and spawning of *S. aurita*. The growth studies of Heald and Griffiths (1967) relied on scales, while those of González (1985) relied on otoliths. Distribution and abundance were estimated from aerial surveys (Trujillo 1976, 1978) and more recently by means of hydroacoustics (Gerlotto and Elquezabal 1986; Ginés and Gerlotto 1988; Anon. 1989).

Despite the knowledge acquired in Venezuela on this resource, there exists a considerable amount of information which has not been analyzed. In this study we present an analysis of historical series of length-frequency data from 1967 to 1989, in order to obtain estimates of growth, mortality, recruitment and available biomass in the fishing area.

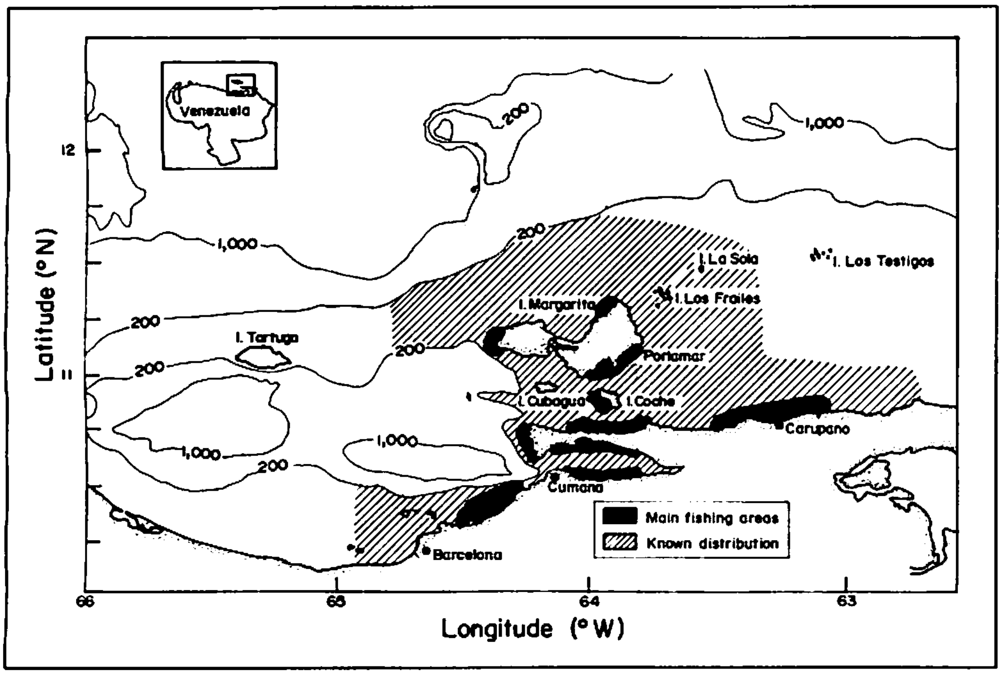

Fig. 1. *Northeastern Venezuela. Map shows main fishing areas and the approximate known distribution of* Sardinella aurita.

Materials and Methods

The database consists of monthly catch and length-frequency data extending for the period 1957-1989, which have been collected by personnel of the Ministry of Agriculture and Animal Husbandry. However, due to variability in data quality, the growth parameter estimates are based essentially on information for the period 1967-1989 and for estimates of fishing mortality, recruitment and biomass on data for the 1976-1989 period. The Compleat ELEFAN (Gayanilo et al. 1989) was used for parameter estimation.

The parameters of the von Bertalanffy Growth Function (VBGF) were obtained through modal progression analysis, following length-frequency decomposition using Battacharya's (1967) method. Estimates of L_∞ and K were obtained using the Gulland and Holt (1959) plot, and subsequently improved using ELEFAN I.

Pauly's model allowed to obtain an approximate value of natural mortality (M), adjusted downward using a factor of 0.8 to account for the schooling behavior of *S. aurita* (Pauly 1980).

Biomass and fishing mortality were obtained from a length-based virtual population analysis (VPA) developed by J. Pope, documented by Pauly and Tsukayama (1983) and Pauly and Palomares (1989) and incorporated as a routine ("VPA III") of the Compleat ELEFAN software package of Gayanilo et al. (1989). In this method the catch equation is generalized as:

$$N_{i+\Delta t}/C_i = Z_i * \exp(Z_i * \Delta t)/F_i * (1 - \exp(Z_i * \Delta t))$$

where

$$\Delta t = 1/K * \ln[(L_\infty - L_1)/(L_\infty - L_2)],$$ and

where

L_1 and L_2 represent the lower and upper boundaries of a given length interval.

As in traditional (age-structured) VPA, the number of individuals in the terminal group was determined from

$$N_t = C_t * Z_t/F_t.$$

Monthly length-frequency and catch data were used in this application of the model. "Pseudocohorts" were obtained from successive monthly growth curves which "sliced" through the catch-at-length data (see Fig. 2). In this analysis a (unique, nonseasonal) growth curve obtained from the average values for the period 1976-1989 was used. In all cases, a moderate level of terminal fishing mortality (F = 0.7, with M = 1.4 $year^{-1}$) was assumed. The transformation of lengths into weights was based on the relationship established by González (1985).

Results

Table 1 shows the growth parameter estimates (L_∞, K and ϕ') for the study period. The yearly values correspond to average growth observed for the different cohorts present in any year. The average values for the study period were L_∞ = 26.6 cm (TL) and K = 1.26 $year^{-1}$; this average growth curve is depicted in Fig. 2.

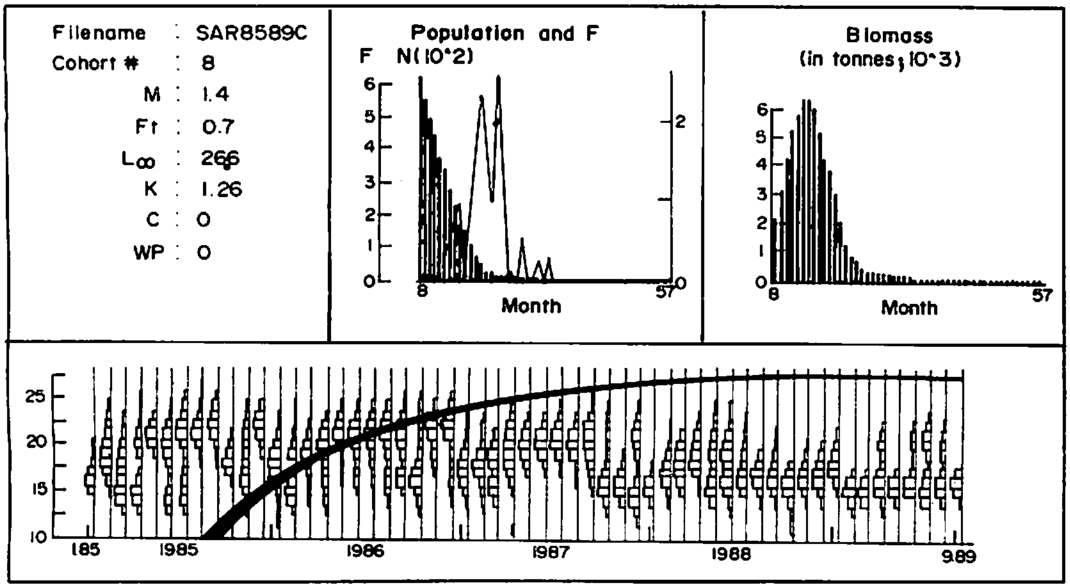

Fig. 2. *Copy of the printer output of the Compleat ELEFAN ("VPA III"), showing how monthly "pseudocohorts" are generated by using two growth curves, drawn at an interval of one month, to identify catch-at-length data (shaded) used to obtain cohort-specific estimates or F and of biomass. Monthly biomass is obtained by pooling the month-specific biomass estimates of different pseudocohorts.*

Table 1. Growth parameter estimates for *Sardinella aurita* from eastern Venezuela (1967-1989).

Year	L_∞ (cm; TL)	K (year^{-1})	ϕ'[a]
1967	24.0	1.05	2.78
1968	24.3	1.29	2.88
1971	27.5	1.20	2.96
1972	27.3	1.50	3.05
1973	26.6	1.40	3.00
1975	28.5	1.75	3.15
1976	26.2	1.45	3.00
1977	27.4	1.02	2.88
1978	24.0	1.40	2.91
1979	27.8	1.04	2.91
1981	23.8	1.04	2.77
1982	29.0	1.25	3.02
1983	25.2	1.20	2.88
1984	28.5	1.10	2.95
1985	28.8	1.10	2.96
1986	26.6	1.35	2.98
1987	26.0	1.40	2.98
1988	27.2	1.68	3.09
1989	26.0	1.10	2.87
Mean	26.6	1.26	2.95

[a]Values of ϕ' were calculated from $\phi' = \log K + 2 * \log L_\infty$ (Pauly and Munro 1984).

Table 2 presents the number of 10 cm recruits into the fishing area per month and year. Generally, we may observe relatively low values (from less than $2 \cdot 10^5$ to $4 \cdot 10^6$ individuals), with a decreasing tendency between 1976 and 1982. This trend is reversed in the following years until maximum values (around 10^9 individuals) are observed at the end of the series. The seasonal signal shows that between 1976 and 1983, higher recruitments occurred from October to February, while between 1984 and 1988, maximum values were observed from June to October.

The biomass estimates by month and year are presented in Table 3. As may be expected, the trend in biomass is similar to that of recruitment. Maximum values (around 100,000 t) are observed at the end of the study period. As in the case of recruitment, there is a change in the seasonal signal during the study period. For 1976-1983, higher biomass values occurred between March and July, while for 1984-1988, the higher values were observed between October and March.

The evolution of fishing mortality is presented in Table 4. The general trend shows a reduction of fishing mortality over time. The seasonal signal had maximum values between May and August in the early years (1976-1983), then changed to higher values in February and March.

Table 2. Estimates of recruitment (in millions) per month and year for *Sardinella aurita* in eastern Venezuela.

Year	Months											
	J	F	M	A	M	J	J	A	S	O	N	D
1976	149.6	113.1	140.5	193.5	198.8	142.3	109.0	107.8	124.5	158.7	208.3	246.2
1977	234.2	180.7	132.8	93.5	60.8	48.2	33.0	50.8	107.4	169.8	173.9	143.1
1978	122.4	101.2	86.6	59.2	66.8	53.0	67.8	62.8	81.8	134.9	194.2	221.5
1979	193.5	153.1	159.8	167.9	66.4	44.9	30.2	33.7	61.9	120.5	176.2	232.0
1980	196.9	216.2	196.6	178.3	154.4	121.8	79.5	44.9	34.5	35.1	50.4	76.7
1981	133.8	105.4	79.7	72.8	67.4	74.1	93.3	125.0	178.0	236.3	262.9	256.6
1982	198.6	110.4	61.7	47.0	41.9	43.2	44.4	49.6	58.8	67.4	76.3	77.9
1983	87.3	86.6	119.0	152.5	172.8	151.9	124.0	112.5	98.8	91.4	100.9	119.5
1984	119.5	130.1	148.4	169.6	194.2	223.0	248.5	254.7	274.4	221.4	193.1	189.6
1985	113.6	122.4	152.4	177.6	209.8	247.0	275.3	258.2	234.3	197.9	180.1	137.8
1986	109.5	105.9	128.6	166.2	192.2	221.9	255.8	266.3	249.4	214.8	187.7	106.0
1987	72.7	71.2	93.7	126.2	182.2	278.3	348.5	359.1	375.9	282.0	162.5	129.0
1988	197.6	244.1	248.6	280.0	344.7	351.7	374.1	313.4	426.6	532.7	649.0	597.7
1989	486.1	296.3	614.7	1,172.8	1,067.2	244.6	-	-	-	-	-	-

Table 3. Estimates of exploited biomass per month and year for *Sardinella aurita* in eastern Venezuela (biomass in thousands of tonnes).

Year	Months J	F	M	A	M	J	J	A	S	O	N	D
1976	14.7	18.7	22.4	25.6	28.6	31.4	31.1	28.6	25.6	22.3	21.6	22.5
1977	24.6	26.4	30.2	34.1	35.0	34.3	29.1	23.7	16.3	14.3	13.9	16.8
1978	16.1	16.9	18.2	17.8	16.2	13.4	11.4	10.1	9.2	9.2	11.1	13.6
1979	17.3	18.3	21.5	20.8	21.6	19.2	17.5	16.7	13.8	14.1	13.6	14.8
1980	18.7	23.2	20.4	22.2	23.2	24.6	25.0	24.4	22.0	20.6	18.3	17.3
1981	9.5	10.2	11.6	12.3	11.7	11.5	11.5	9.8	12.0	16.2	20.3	26.1
1982	31.6	35.0	35.8	35.7	34.6	32.5	30.2	27.8	25.6	23.8	22.7	21.6
1983	21.4	21.4	22.0	21.8	22.8	25.1	27.3	28.1	28.1	28.0	27.9	27.5
1984	28.5	29.5	31.5	31.6	33.2	34.0	35.4	38.0	39.8	42.5	44.5	47.1
1985	50.4	51.2	50.8	50.1	50.1	48.8	49.2	50.2	48.1	46.6	43.8	42.0
1986	46.4	47.3	46.3	45.3	42.5	44.3	44.3	43.6	42.8	42.1	42.7	43.9
1987	45.8	45.0	43.0	40.0	37.6	35.8	37.0	37.4	39.5	41.0	43.1	45.6
1988	48.9	46.6	42.3	39.4	38.5	37.8	38.1	38.2	41.3	44.7	48.6	55.0
1989	62.7	71.1	78.5	89.9	105.2	117.2	-	-	-	-	-	-

Table 4. Monthly estimates of fishing mortality (F; year⁻¹) for *Sardinella aurita* in eastern Venezuela.

Year	Months J	F	M	A	M	J	J	A	S	O	N	D
1976	.01	.08	.34	.48	.42	1.06	1.16	1.23	2.28	1.34	.75	.60
1977	.67	.16	.08	.66	.76	1.82	2.21	2.69	1.56	.66	.13	.97
1978	.72	.83	1.17	1.04	2.09	2.19	1.60	1.48	1.35	.54	.56	.18
1979	.52	.37	1.42	.88	1.33	1.44	1.04	2.10	.84	1.48	.84	.11
1980	.04	.54	1.24	1.11	.97	1.18	1.22	1.56	1.27	1.40	.95	.64
1981	.97	.61	1.30	1.96	1.63	1.25	2.76	.28	.05	.23	.22	.16
1982	.52	.91	.72	1.00	1.27	1.07	.97	.95	.74	.58	.61	.41
1983	.40	.32	1.23	.39	.25	.28	.56	.94	.87	.79	.89	.52
1984	.56	.41	.90	.44	.57	.74	.66	.68	.65	.72	.56	.32
1985	.62	.54	.75	.44	.37	.62	.56	.53	.36	.63	1.30	.03
1986	.52	.94	.75	.98	.25	.55	.63	.68	.73	.81	.35	.23
1987	.78	.93	1.19	.94	.90	.50	.61	.52	.49	.66	.66	.32
1988	1.56	1.60	1.29	.92	1.13	.90	.63	.84	.91	1.10	.70	.52
1989	.31	.61	.59	.32	.42	.38	-	-	-	-	-	-

Discussion

Our growth studies, based on length-frequency analysis, indicate that *Sardinella aurita* growth in eastern Venezuela is rapid. These contrast with the relatively slow growth rates for the same area suggested by Heald and Griffiths (1967) and González (1985), based on hard structures. However, the results of Gheno (1975) and Fréon (1988) for west Africa, also using length-frequency analysis, are comparable to ours. Furthermore, Mendoza (1993) determined from an application of the ECOPATH approach (Polovina 1984; Christensen and Pauly 1991) in eastern Venezuela that a fast growth rate was compatible with the predatory pressure exerted upon this species within the ecosystem.

Length-structured VPA may present an autocorrelation effect (Mendelssohn and Mendo 1987; Pauly and Palomares 1989) caused largely by differences in individual growth within "pseudocohorts". In the present case this effect is probably magnified by the use of a single non-oscillating growth curve. For this reason the seasonality of the monthly estimates of recruitment was not emphasized in this paper, except for the fact that we observed a change in the location of the maxima during the period, which probably reflects other underlying causes, such as changes in environmental variables, resource availability and/or reproductive pattern.

The nature of the fisheries in eastern Venezuela imposes certain limitations on the application of length-structured VPA. Our results and hydroacoustic surveys (Anon. 1989) indicate that the exploitation level is low. Under these circumstances, the uncertainty associated with the natural mortality estimate and different sources of variability in this parameter affect the degree of confidence which may be put on quantitative results. These will also depend on the level of interchange (i.e., movement) between the exploited fraction and the rest of the population at any time. The assumption of a moderate exploitation level (E = F/Z = 0.33) for all cohorts implies that this interchange occurs at an intermediate rate.

Despite the above mentioned limitations, our results are compatible with existing knowledge on this resource. For example, the VPA estimates of biomass suggest that around 15% of the total standing stock estimated from hydroacoustics was available in the restricted fishing area at the end of the study period. Further research and more intensive sampling is required in order to tune the VPA using independent biomass estimates within the fishing area. In this case, assuming no major temporal changes in natural mortality, the observed yearly trends in recruitment to the fishery and exploited biomass would remain essentially the same. Research is underway to identify possible relationships between the biomass and the recruitment of *S. aurita* off eastern Venezuela, and their relationship to various environmental parameters.

Acknowledgement

Our thanks to Dr. Daniel Pauly for inviting this contribution for *Naga* and for his useful comments on our work. This is CEOS Contribution No. 46.

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