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The Fisheries Biology of the Big-Eye Scad, *Selar crumenophthalmus* (Bloch) in the Philippines

P. DALZELL^a

*International Center for Living Aquatic Resources Management
MC P.O. Box 1501, Makati, Metro Manila, Philippines*

G. PEÑAFLOR^b

*Department of Fisheries
University of the Philippines in the Visayas
Diliman, Quezon City, Philippines*

Abstract

Age and growth of *Selar crumenophthalmus* (Pisces, Carangidae) from the Philippines were determined through the use of otolith daily growth increments and fish length-frequency data. The methods showed good agreement for computed growth parameters. Ages estimated from otoliths agreed well with those of the same species from the Mariana Islands, also determined by otolith microstructure. Apparent mortality rates, lengths at first capture and recruitment patterns were established from length-frequency data. Mortality rates and exploitation rates were high; sources of bias are discussed. Recruitment appears to occur in two pulses during the year, between four and five months apart. Catch rates of *S. crumenophthalmus* are highly seasonal, reflecting not only changes in biomass but also certain behavior associated with life-history stages.

Introduction

Catches of big-eye scads of the genus *Selar* (Fam. Carangidae) account for about 6% of small pelagic fishes landed in the Philippines and 3% of all marine landings there (Dalzell and Ganaden 1987). The genus contains two species, *Selar crumenophthalmus* and *S. boops*. Recent sampling data in the Philippines on small pelagic landings (Dalzell et al., in press) suggest that about 85% of big-eye scad

^aPresent address: South Pacific Commission, BP D5 Noumea, New Caledonia.

^bPresent address: Laboratory of Marine Fishery Resources, Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima City 890, Japan.

landings comprise *S. crumenophthalmus*. This species has a circumtropical distribution and makes important contributions to small-scale fisheries catches in the Caribbean, Southeast Asia and the South Pacific (Bagnis et al. 1974; Fischer 1978; Dalzell and Ganaden 1987). In Hawaii, *S. crumenophthalmus* is an important commercial and recreational species and commercial fishermen employ sophisticated techniques such as spotter planes to maximize catches (Kawamoto 1973).

The most comprehensive account of *S. crumenophthalmus* biology is given by Kawamoto (1973) for Hawaiian waters and includes details of age, growth, reproduction, feeding habits and mortality. The growth of *S. crumenophthalmus* in Indonesian waters as inferred from length-frequency data was described by Sadhatomo and Atmadja (1985). Ralston and Williams (1988) aged *S. crumenophthalmus* from the Mariana Islands (Micronesia) by counts of the daily growth increments of the sagittae. In the Philippines, Ingles and Pauly (1984) analyzed length-frequency data for *S. crumenophthalmus* from Manila Bay to estimate growth, mortality and recruitment parameters. Similar studies have been made with length data for *S. crumenophthalmus* from the Sibuyan Sea (Philbrick 1987) and for *Selar boops* from the southern Philippines (Dy-Ali 1988). Jabat and Dalzell (1988) included *S. crumenophthalmus* in their study of a ring net fishery based at Danao in the Camotes Sea, Central Philippines, and used length-frequency data extending over a five-year period to estimate growth, mortality and recruitment parameters.

Corpuz and Dalzell (1988) recorded a total of eleven gears used for capture of big-eye scads in the Philippines. Besides purse seines, trawls and ring nets, big-eye scads were captured with lamparas, drive-in-nets, gill nets, hand lines, hoop nets, fish corrals, bagnets and beach seines.

In this paper, further studies on Philippine *S. crumenophthalmus* stocks are reported from five different locations, including the Camotes Sea, based on data collected during an investigative program designed specifically to gather information of Philippine small pelagic fish stocks (Dalzell et al. 1988).

Materials and Methods

Landings of small pelagic fishes in the Philippines were sampled at eight locations between February 1987 and March 1988 (Fig. 1).

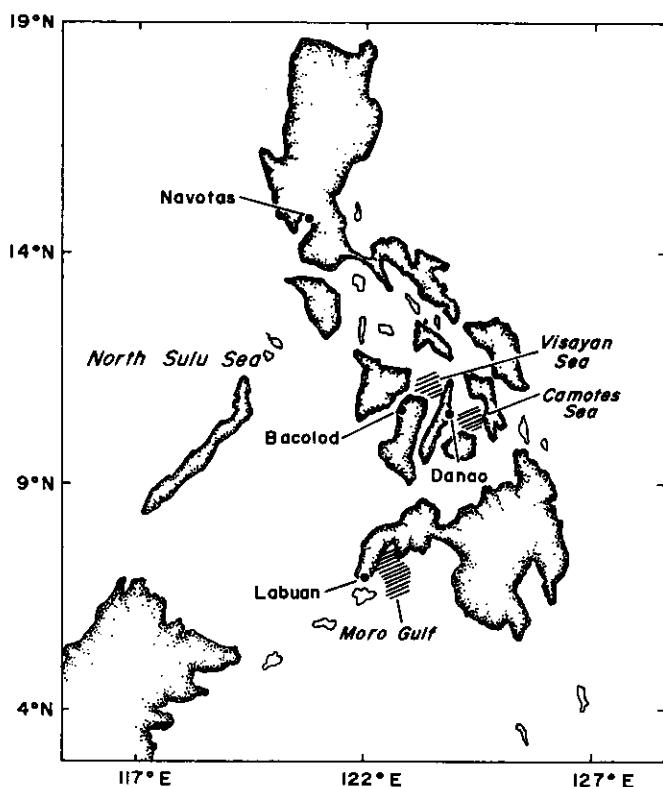


Fig. 1. Landing sites and fishing grounds where information on *S. crumenophthalmus* was collected in the Philippines, 1987 to 1988.

Sampling was conducted at each landing site for 20 days of each month. Records were routinely collected of catch, catch composition and fishing effort of the different gear-vessel combinations landing small pelagic fishes. Samples were taken to determine species composition and lengths of small pelagic fishes were measured from the tip of the snout to the tip of the outstretched caudal fin, i.e., total length (TL). Measurements were made to the nearest 0.1 cm and were later grouped into 1.0-cm length classes, summarized on a monthly basis.

The fishing gears recorded here employed to catch *S. crumenophthalmus* were purse seines, ring nets and trawls. A detailed account of the dimensions of these gears in the Philippines and their mode of operation is given by Dalzell et al. (in press). Both purse seiners and ring netters normally fish at night around "payaos"

or fish aggregating devices. These are commonly employed by Philippine fishermen to aggregate tuna and other pelagic species. They consist either of anchored bamboo or metal pontoon rafts from which vegetation, usually coconut fronds, are hung (Murdy 1980). Purse seiners and ring netters also employ powerful lights to concentrate the fish schools at night before deploying their nets. The lights may be mounted on the fishing vessel itself and/or on special smaller light boats.

Catch data were also grouped on a monthly basis and landings of both *S. crumenophthalmus* and *S. boops* were reported collectively as big-eye scads. This was broken down into the respective species from the species composition data. Four sets of catch-and-effort data were used here to investigate seasonality of *S. crumenophthalmus* catches. These are summarized in Table 1a. In some locations, the catch record was too fragmentary to be of use due to infrequency of big-eye scad landings. At Navotas (Manila) fish port, all landings are made by ancillary carrier vessels rather than the fishing vessels themselves. Thus, catch but not effort data were recorded.

Table 1a. Summary of landing sites, fishing grounds and collected data on *S. crumenophthalmus* in the Philippines, 1987 to 1988. Crosses indicate data collection.

Landing site	Fishing ground	Fishing gear	Catch data	Effort data	Length frequencies	Otolith readings
Navotas	N. Sulu Sea	Purse seine	x		x	
Bacolod	Visayan Sea	Purse seine	x	x	x	
Bacolod	Visayan Sea	Trawl	x	x	x	
Danao	Camotes Sea	Ring net	x	x	x	x
Labuan	Moro Gulf	Ring net	x	x	x	

The ages of 25 specimens of *S. crumenophthalmus* from the Camotes Sea and ranging in length from 9.3 to 25.0 cm were determined by counts of daily growth increments (Panella 1971) of the sagittal otoliths. The otoliths were extracted from the cranium with fine forceps following a lateral dissection along the middorsal section of the head. The otoliths were then cleaned and stored dry. Prior to the observations of otolith microstructure by either light or scanning electron microscopy (SEM), the axial length of the otoliths was measured, from the rostrum tip to the postrostrum. Otoliths examined under light microscopy were first ground using fine carborundum paper (600 grit) then rinsed in water and dried. They were then mounted in immersion oil for counting at 400x

magnification. Counts were made from the nucleus to the postrostrum. The increments on each otolith were counted twice. To reduce the risk of biased counts, they were simply labeled with a reference number. A second set of counts was also made with the otoliths relabeled with different reference numbers.

Initial examinations of the *S. crumenophthalmus* otoliths were made using SEM to ascertain that the smallest increments were with the resolving power of the optical microscope (Morales-Nin 1988). Unground otoliths were etched with a 7% ethylene diamine tetra acetate (EDTA) solution, adjusted to pH 7.4 with sodium hydroxide. Etching times depended on the size of the otolith but never exceeded five minutes. During the period of etching, the otolith was observed under light microscopy to check the visibility of growth increments. After etching, the otoliths were cleaned then mounted on a brass SEM stub and gold coated in a vacuum for four minutes prior to examination.

Analyses of five length-frequency data sets (Table 1b) for growth, mortality selection and recruitment parameters were made using the ELEFAN computer programs (Pauly 1987).

Table 1b. Sample sizes for *S. crumenophthalmus* collected from different locations in the Philippines.

Month	Visayan Sea (purse seine)	Visayan Sea (trawl)	Moro Gulf (ring net)	Camotes Sea (ring net)	Northern Sulu Sea (purse seine)
1987					
F	0	10	49	398	46
M	0	9	33	382	115
A	12	0	140	769	161
M	30	21	88	790	85
J	72	34	120	934	137
J	86	32	180	1,833	167
A	181	46	623	1,543	60
S	79	109	258	516	185
O	68	130	245	1,211	120
N	92	26	124	1,479	124
D	0	0	72	1,735	11
1988					
J	68	13	63	580	99
F	14	108	140	985	0
M	0	26	170	1,047	19
A	89	16	60	181	96

The total mortality rates (Z) of the different *S. crumenophthalmus* stocks were determined from length-converted catch curves (Pauly 1984). The catch curve was used to construct a resultant curve (Gulland 1983) which expresses the interaction of mesh selection with recruitment. Natural mortality rate (M) was estimated from the empirical equation of Pauly (1980). Mortality and selection parameter estimates are routines incorporated in ELEFAN II.

Results

Catch Rates and Seasonality

The changes in monthly mean catch rate (kg/haul) of *S. crumenophthalmus* are shown expressed on a calendar year in Fig. 2 for purse seiners and trawlers operating in the Visayan Sea, and for ring netters in the Camotes Sea and Moro Gulf. The maximum catch per effort of *S. crumenophthalmus* in the Camotes Sea occurred after July with a pronounced peak during November to January. These results are similar to those of Jabat and Dalzell (1988) for the same stock using five years of catch and effort data. This pattern is also similar to that for *S. crumenophthalmus* landed into Navotas from all parts of the Philippines (Dalzell and Ganaden 1987). By contrast, catch rates of this species caught by ring nets in the Moro Gulf showed a minor peak of production between March and April followed by a major peak between June and September.

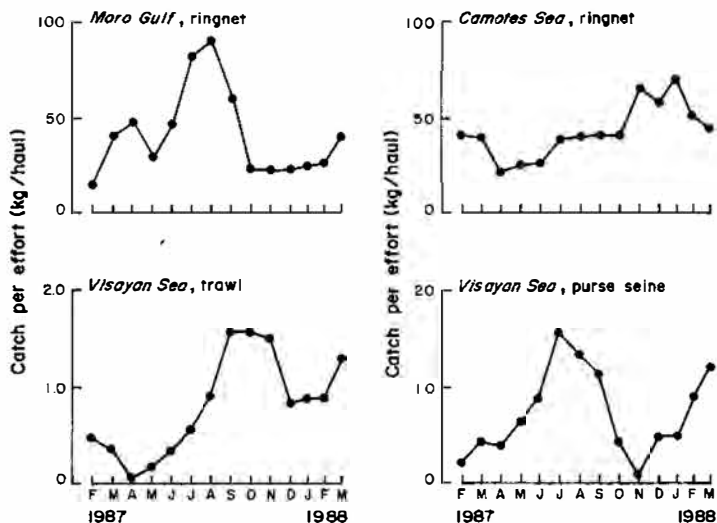


Fig. 2. Changes in mean monthly catch per effort for catches of *S. crumenophthalmus* in the Philippines.

The major peak in catch rates for the purse seiners in the Visayan Sea was also between June and September, with a pronounced decline after September. Although in the same location, trawl catches of *S. crumenophthalmus* resembled more those of ring netters in the Camotes Sea with a major production peak between September to November.

Age and Growth

The plot of otolith length versus fish length for *S. crumenophthalmus* is shown in Fig. 3 and demonstrates their clear proportionality. It was beyond the scope of this study to validate the daily periodicity of the increment formation. However, the increments appeared to be structurally homologous with those of fishes where the daily nature of ring deposition has been validated (Fig. 4). If the rings are daily in nature, then growth of *S. crumenophthalmus* in the first year of life is rapid. The size of this species from the Camotes Sea after one year is about 23 cm (Fig. 5).

The scatter of age versus length for *S. crumenophthalmus* is shown in Fig. 5, fitted by a von Bertalanffy growth function (VBGF) following the least squares method of Beverton (in Ricker 1975). The VBGF is linearized such that a plot of $\log_e (L_\infty - L_t)$ versus t produces a straight line with a negative slope, the value of which is equal to K . The ordinate intercept can be equated to $\log_e L_\infty + Kt_0$ and hence t_0 can be estimated. The asymptotic length was iterated to give the best fit to the data points such that:

$$L_t = 29.83 (1 - e^{-1.94 (t-0.228)}) \quad r^2 = 0.904$$

The standard errors of the growth constant K and t_0 were ± 1.415 and ± 0.923 , respectively.

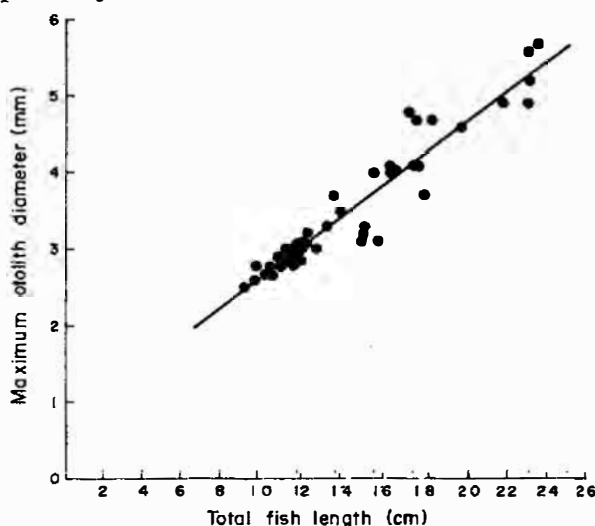


Fig. 3. Maximum otolith diameter versus total fish length for *S. crumenophthalmus*, Camotes Sea.

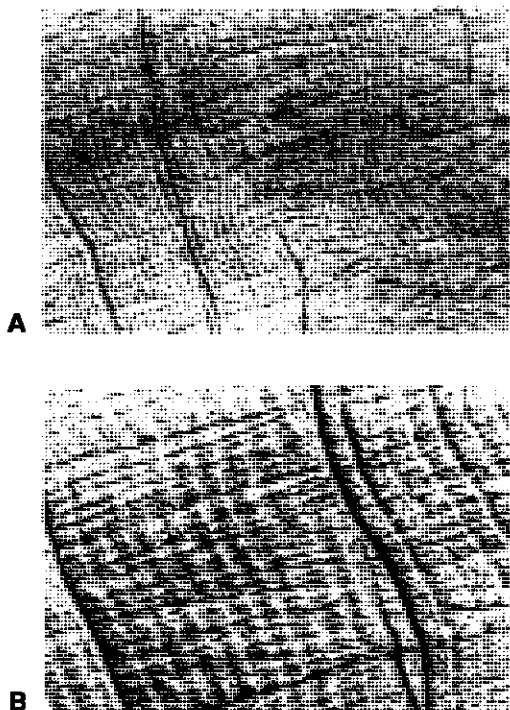


Fig. 4. Electron micrographs of *S. crumenophthalmus* sagittal otolith and daily growth increments. Both micrographs show increments towards the postrostral margin, with magnification of A = $\times 800$ and B = $\times 2,000$. The black bar in the lower right corner corresponds to 10 μm .

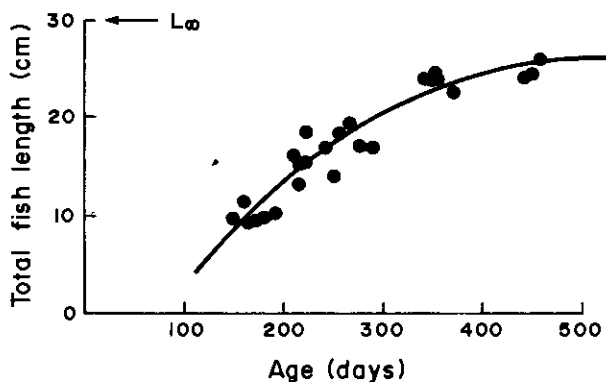


Fig. 5. Length versus age from daily growth increment readings of *S. crumenophthalmus* otoliths and the VBGF fitted to the scatter of points.

Examples of the length-frequency data sets for *S. crumenophthalmus* with growth curves fitted by ELEFAN I are shown in Fig. 6. In the case of the data from the Visayan Sea, Camotes Sea, North Sulu Sea and Moro Gulf, it was possible to fit two growth curves to the data to show that two cohorts are growing through the population each year. A summary of the growth parameters estimated from each length data set is given in Table 2.

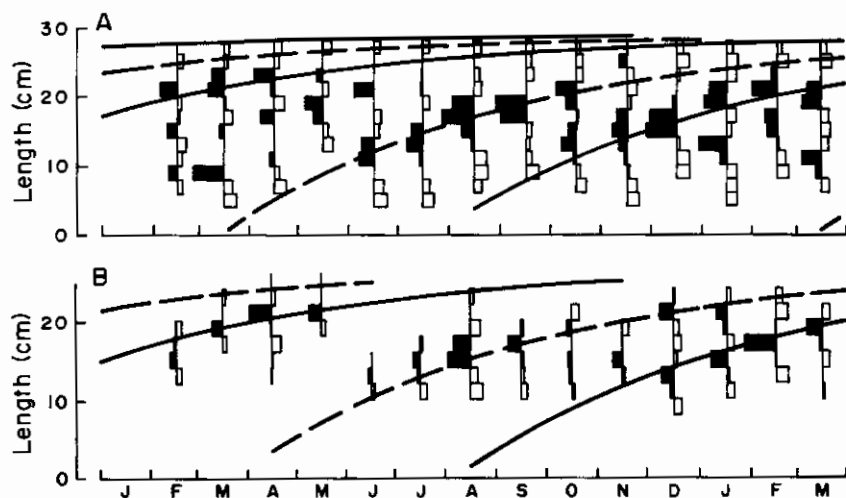


Fig. 6. Examples of length-frequency data for *S. crumenophthalmus* showing transformation into peaks (black) and troughs (white) and with fitted growth curves. A. Landed by ring netters in the Camotes Sea. B. Landed by ring netters in the Moro Gulf.

Table 2. Growth, mortality and related parameters for Philippine stocks of *S. crumenophthalmus* determined from length-frequency data.

Location	L_{∞} (cm)	K (year ⁻¹)	ϕ'	Z (year ⁻¹)	M (year ⁻¹)	F (year ⁻¹)	E	L_{50} (cm)
Visayan Sea	31.6	1.80	3.25	7.519	2.599	4.92	0.654	21.1
Visayan Sea	31.5	1.70	3.23	5.968	2.506	3.462	0.560	23.7
Moro Gulf	27.0	2.00	3.16	9.039	2.909	6.130	0.678	13.8
Camotes Sea	31.2	1.77	3.24	10.028	2.584	7.444	0.742	13.2
Northern Sulu Sea	29.0	2.05	3.24	6.106	2.898	3.208	0.525	21.2

Mortality

The length-converted catch curves for *S. crumenophthalmus* from the Philippines are shown in Fig. 7 and the estimates of total mortality rates (Z) are included in Table 2. These suggest that the fishing mortalities (F) are very high in each instance.

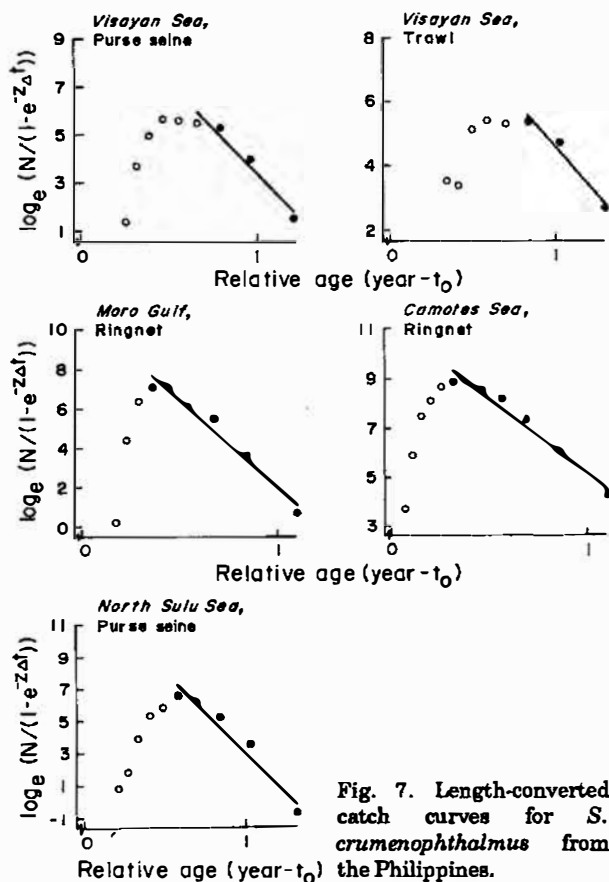


Fig. 7. Length-converted catch curves for *S. crumenophthalmus* from the Philippines.

Length at First Capture

The selection ogives generated by the length-converted catch curves for Philippine *S. crumenophthalmus* stocks are shown in Fig. 8. Both trawl and purse seines in the Visayan Sea and purse seines in the northern Sulu Sea produce high first-capture lengths (21 to 24.0 cm) (Table 2). Given the small mesh size of all these gears (1 to 2.0 cm), however, the value of L_{50} for a given stock is likely to be a reflection of recruitment rather than selectivity. This is also true for fish captured by ring nets in the Moro Gulf and Camotes Sea where the L_{50} is about 13 cm. The selection curves are in reality resultant curves, that is, an apparent selection pattern generated through the interaction of recruitment process and selection effects (Gulland 1983).

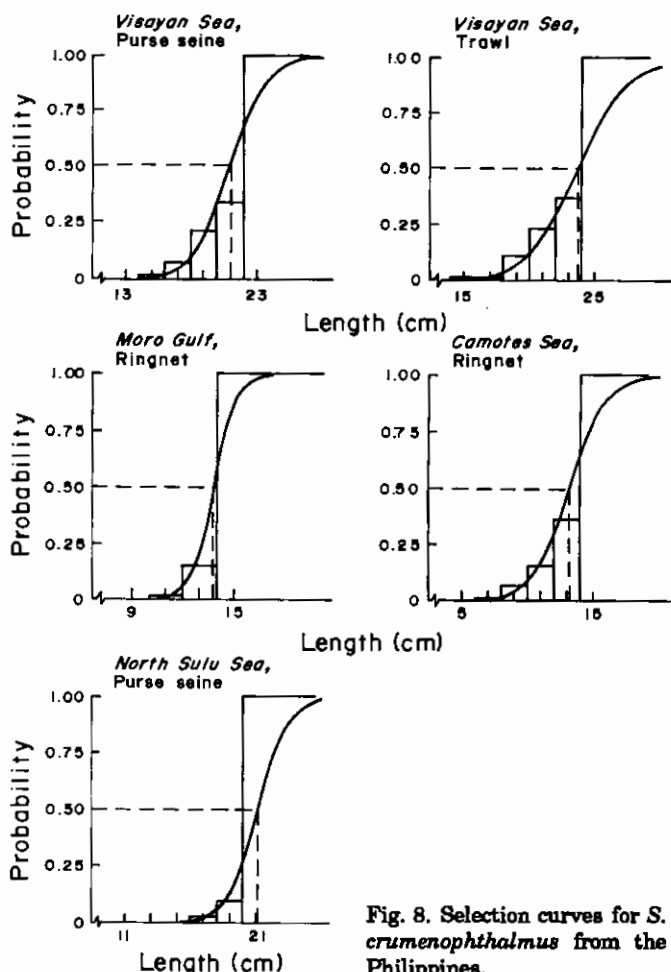


Fig. 8. Selection curves for *S. crumenophthalmus* from the Philippines.

Recruitment Patterns

The recruitment patterns of the different Philippine stocks of *S. crumenophthalmus* are shown in Fig. 9. The patterns for the Camotes Sea and northern Sulu Sea stocks are clearly bimodal with 4 to 5 months separating peaks. The recruitment patterns generated by the length data from the Moro Gulf and Visayan Sea are less clearly bimodal; indeed the data for *S. crumenophthalmus* captured by trawls suggest a single unimodal recruitment pulse. A major peak in recruitment is also evident from the data of purse seine-caught *S. crumenophthalmus* but the spread of frequencies suggests a minor secondary peak in recruitment.

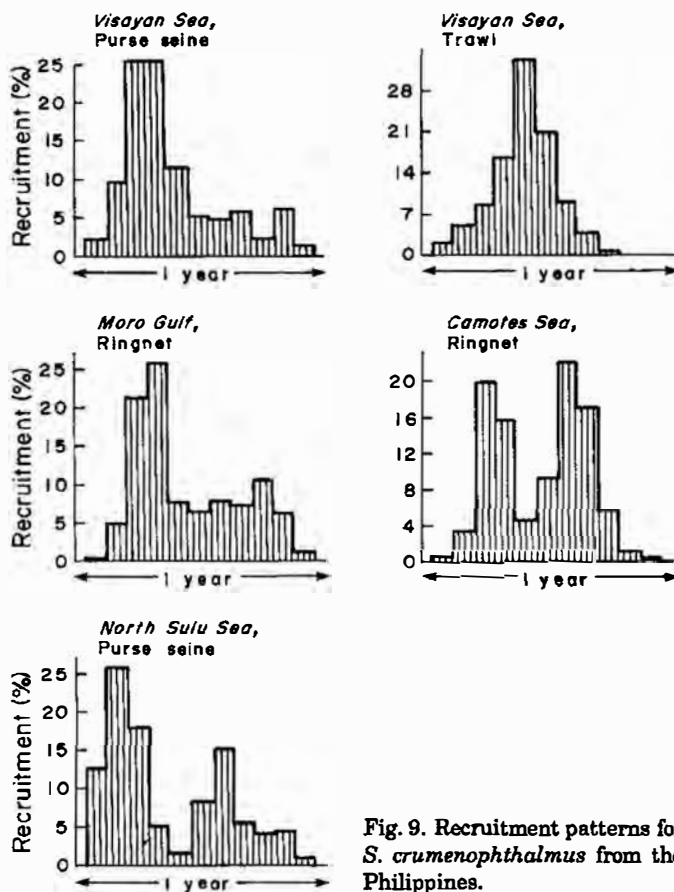


Fig. 9. Recruitment patterns for *S. crumenophthalmus* from the Philippines.

Discussion

Ralston and Williams (1988) made some limited observations for *S. crumenophthalmus* from the Mariana Islands in the Western Pacific. Specimens of 21.5, 24.7 and 27.7 cm fork length (24.3, 27.8 and 31.3 cm TL) were found to be 330, 550 and 880 days old, respectively. The observations for the two smaller fish agree well with age-at-length for *S. crumenophthalmus* from the Camotes Sea. No fish from the Camotes Sea larger than 25.0 cm were examined here for age estimation. According to Ralston's data, *S. crumenophthalmus* may have a longevity of about 2.5 years.

Morales-Nin (1988) has cautioned against the use of otolith microstructure to age fish using only optical microscopy. A thorough

examination of otoliths by SEM is necessary prior to making counts of daily growth increments. Partial validation that at least the increment counts were accurate came from the limited observations of Ralston and Williams (1988) for *S. crumenophthalmus* from the Mariana islands. The good agreement between length-frequency-generated growth parameters and those from otolith readings are partial validation for daily deposition, although the evidence for this is circumstantial following the criteria discussed in Brothers (1983).

The various growth parameter estimates for *Selar* spp. from the Philippines and elsewhere are summarized in Tables 2 and 3. These parameters cannot be compared directly but may be used to compute the parameter ϕ' where:

$$\phi' = \log_{10} K + 2 \log_{10} L_{\infty}$$

Pauly and Munro (1984) and Moreau et al. (1986) showed that for a given species or species group, ϕ' should be normally distributed with a coefficient of variation (CV = S.D./mean 100) of $\leq 10\%$. Even with the limited data available here, it is clear that the ϕ' estimates are not normally distributed given the disparity in the estimates of the growth parameter K.

Table 3. Growth parameter estimates for *Selar* spp. from the Philippines, Indonesia and Hawaii.

Species	Location	L_{∞} (cm)	K (year ⁻¹)	ϕ'	Method
<i>S. crumenophthalmus</i>	Hawaii	27	2.57	3.273	Tagging
	Manila (Phila.)	36.5	0.89	3.074	ELEFAN I
	Indonesia	28.9	1.35	2.990	ELEFAN I
	Marinduque (Phila.)	26.5	1.25	2.943	ELEFAN I
	- do -	28.8	0.86	2.853	ELEFAN I
	Mariana Is.	31.9	0.61	2.743	Otoliths
<i>S. boops</i> ^a x	Davao (Phila.)	28.9	1.96	3.214 3.063	ELEFAN I

^aThis is now thought to be *Selar crumenophthalmus* that was incorrectly identified.

Initial analyses of the length data showed that with $L_{\infty} = 30.0$ cm, the length frequencies could be fitted equally well by ELEFAN with $K \approx 1.0$ or $K \approx 2.0$. This problem was also encountered by Jabat and Dalzell (1988) by Dy-Ali (1988) for *S. crumenophthalmus* and *S. boops*, respectively. Dy-Ali opted for the higher K and let the program

optimize from this. Jabat and Dalzell (1988) used a lower K value for optimization based on similar length-frequency analyses (Ingles and Pauly 1984; Sadhatomo and Atmadja 1985; Philbrick 1987). This would appear now to be erroneous given the evidence from daily growth increment analysis and also from earlier growth parameter estimates made from tagging of *S. crumenophthalmus* in Hawaii (Kawamoto 1973).

The low K value of Ralston and Williams (1988) for their otolith readings is a consequence of fitting the VBGF to data where juvenile age estimates were absent. Thus, whilst K was very low, the origin of the curve, t_0 , was abnormally high for a short-lived fish ($t_0 = -350$ days). Growth parameters estimated by other authors for *S. crumenophthalmus* using ELEFAN I may have underestimated growth rates, particularly where juvenile fish are underrepresented in the samples as is the case with the data of Sadhatomo and Atmadja (1985) and Philbrick (1987).

The ratio of F/Z or exploitation rate (E) is a measure of the intensity by which a fish stock is exploited. Gulland (1971) has suggested that if a stock is optimally exploited, then fishing mortality is equal to natural mortality or $F_{opt} = M$ and $E = 0.5$. Pauly (1984), based on Beddington and Cooke (1983), has proposed a more conservative optimum fishing mortality where $F_{opt} = 0.4M$ or $E = 0.3$. By both these definitions, the stocks of *S. crumenophthalmus* would appear to be overexploited. This conclusion is based, however, on the assumption that the catch curves give true estimates of Z and that Pauly's (1980) equation computes a reasonable approximation of M. Given the broad confidence limits of M from the equation (Pauly 1980; Gulland 1988), the results cannot be regarded as conclusive. Further, the estimates of Z from the catch curves may be upwardly biased from migration effects of larger and older fish, particularly away from payaos which are used in conjunction with purse seines and ring nets. Such effects were discussed by Jabat and Dalzell (1988) and Tandog-Edralin et al. (1988) in connection with catches of coastal tunas and small pelagic fishes from the Philippines.

The seasonality in the abundance of *S. crumenophthalmus* as observed here in the Philippines may be a combination of actual changes in species biomass and the behavior of the fish. Given the short life span of this species, the recruitment each year constitutes the bulk of the fisheries catch and the seasonality of abundance is largely a function of recruitment seasonality. However, the differences in the fluctuation of catch rates of *S. crumenophthalmus*

captured by trawls and purse seines in the same location, the Visayan Sea, is suggestive of some form of migratory movement.

Johannes (1981) has observed that accounts of increasing mean size of fish with depth are common in the literature. Further, such accounts are not restricted to pelagic species. Longhurst and Pauly (1987) suggest that size-specific migration into deeper water is a mechanism for lowering maintenance metabolism; hence, fish grow larger. The modal size of *S. crumenophthalmus* caught by demersal trawls in the Visayan Sea is 24.0 cm, compared with 16 to 20 cm for the same species caught there and elsewhere in the Philippines by pelagic gears. Souza (1988) has shown that specimens of the roundscads, *Decapterus russelli*, of the same age taken by pelagic trawls off Mozambique are on average smaller than those captured by demersal trawling. Size stratification by depth will naturally introduce bias into the estimation of age, growth and mortality parameters. Declines in apparent abundance in surface waters may also be due to size-related migration into deeper water where fish became less vulnerable to purse seining but can be captured by trawling.

The separation of sequential length-frequency data into two cohorts leads to the mostly bimodal recruitment patterns in Fig. 9. The timing of spawning and recruitment is probably a reflection of the influence of monsoon seasonality in the Philippines as suggested by Pauly and Navaluna (1983) and Navaluna and Pauly (1988) for many other fish species in the Philippines.

Catches of *S. crumenophthalmus* and *S. boops* are usually not the prime focus of most pelagic fisheries and are common incidental species in catches. Overall, the big-eye scads rank fifth behind roundscads, sardines, anchovies and mackerels in Philippine small pelagic fish catches (Dalzell and Ganaden 1987). Differences in first-capture lengths can be shown for different gears and the effects of this determined by yield-per-recruit analysis (Gulland 1983). However, the results are inapplicable in such a multispecies fishery where many different component species have individual optimum lengths and age at first capture. Further, it is probably the case for many small pelagic species in the Philippines (Dalzell, unpubl. data) that the observed size at first capture is a recruitment-rather than selection-related function. Attempts to estimate optimum mesh sizes, as has been done for the Philippine multispecies demersal fishery (Silvestre 1986) will not, under such circumstances, be appropriate.

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