Editorial

The following four papers, from Africa, Asia and South America continue the *FISHBYTE* tradition of presenting both methods-oriented papers and papers that describe fisheries and their resource base. Here the mix is two of each.

I am particularly happy about the paper on *Octopus* recruitment, which supports my often-stated belief that seasonal growth oscillations of fish and aquatic invertebrates, when quantified and put into an ecological context, can help identify important aspects of the life-history of these resources. Of equal importance is the fact that explicit consideration of seasonal growth oscillation helps reconcile what may initially appear to be mutually contradictory information. Thus, congratulations to Paco, and onward with the good work. ***D. Pauly***

Growth and Seasonal Recruitment of *Octopus maya* on Campeche Bank, Mexico

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Abstract

A study of growth and seasonal recruitment of the cephalopod *Octopus maya* on Campeche Bank, México, was conducted, based on catch at size data sampled from 1983 to 1988. The parameters of a seasonally oscillating version of the von Bertalanffy growth function and total mortality estimates were obtained via the ELEFAN software. It was found that when recruitment occurs early in the year, the growth curve of the next year does not display seasonal oscillations, and conversely. Total mortality estimates ranged from Z = 2.6 to Z = 6.3/year.

Introduction

The fishery for the cephalopod *Octopus maya* is very important along the northern and west coast of the Peninsula of Yucatan in the Gulf of México, both for the small-scale fleet whose catches are composed mainly by one species, *O. maya*, and the industrial fishery whose catches are composed of *O. maya* (70%) and *O. vulgaris* (30%) (Seijo et al. 1987). The fishery was initiated in 1956 by the small-scale fleet, with an annual catch of 50 t, while the industrial fleet began operations in 1982. The fishing season ranges from 1 August when the first spawning aggregation occurs, to 15 December. The annual catch yields averages approximately 8,000 t, with a range from 5,600 t in 1988 (Rihani et al. 1988) to 14,000 t in 1990. Octopuses are caught using a fishing gear locally named "jimba", consisting of a large rod with several lines baited with crabs. Fishing operations are conducted from single boats which drift during fishing from the coastline to depths of 5-15 m (Arreguín-Sánchez et al. 1987).

Solís-Ramirez and Chávez (1986) analyzed the catches of the 1980 fishing season; Seijo et al. (1987) applied a stochastic model for a bioeconomic simulation of the 1986 fishing season (both fleets). As result of this simulation, they suggested delaying the opening of the fishing season by two weeks. On the other hand, Arreguín-Sánchez (in press) applied a Schaefer model to the small-scale fishery and estimated the time of recovery of the exploited population. He also recommended a reduction of the fishing season; however, considering the recruitment pattern for 1985 obtained with the ELEFAN II program, he suggested that the end of the fishing season was the best time for a reduction.

The exploitation of octopus is carried on during the reproductive season when the population is concentrated near the coast, when and where water turbidity is high. In years when the time of increasing turbidity is delayed, fishers remain in ports until turbidity increases. This phenomenon and the results of the stock assessments mentioned above suggest that timing of the reproduction season is influenced by environmental variables, although the specific mechanisms involved are not yet known.

This paper is concerned with the analysis of growth and seasonal recruitment pattern of *O. maya* based on catch-at-length data from the 1983 to 1988 fishing seasons.

Methods

The available data were obtained from the commercial catch samples from several fishing ports, and directly from beachside landings. Sampling was based on a two-stage design considering both fishing ports and boats. For ports, a proportional size design was used which accounted for the fact that most of the fishing operations of the small-scale fleet are concentrated on the northwest coast of Yucatan; for the fishing boats a random selection was made. Measurements of individual octopuses refer to mantle length, in mm.

Growth analysis was performed from monthly mantle length-frequency data, to which the ELEFAN I program of Brey and Pauly (1986) was applied.

To enable differences of growth between years to be identified, data for each fishing season (4.5 months) were analyzed separately; this was possible because octopus is a short-lived species whose life cycle is completed approximately in one year; [*O. maya* longevity was reported by Caddy (1983) to range between one and two years; van Heukelem (1977) reported a longevity of 8-12 months in the laboratory].

After these estimations, recruitment pattern and total mortality from length-converted catch curves were obtained, using the ELEFAN II program, for each year. These estimates were then compared with estimates of L_∞ and Z/K parameters obtained by application of the method of Wetherall et al. (1987).

Results and Discussion

Table 1 presents the growth parameter estimates obtained with the ELEFAN I program. The K values ranged from 0.8 to 2.4/year; and L_∞ from 194 to 245 mm which suggest a high between-year variability of growth. To verify this, the ELEFAN I analyses were also performed using the square root of the numbers of octopuses per length interval instead of the original numbers. The results thus obtained are shown on the second part of Table 1. Here, K values ranged between 0.9 and 1.3/year, and L_∞ between 216 and 238 mm. Although both procedures produced variable results, the mean values of K and L_∞ obtained by these two approaches are practically the same. However, a single comparison of the growth index ω (where $\omega = KL_\infty$) (Gallucci and Quinn 1979) indicates significant differences between both approaches (from a t-test with $\alpha = 0.05$).

Seasonal growth was detected for the 1985-87 cohorts (Fig. 1), but not for others. The values of the parameters C (amplitude of seasonal growth oscillation) and WP (time of the year where reduction of growth is strongest) of the seasonal growth equation proposed by Pauly and Gaschütz (1979) ranged between 1.4 and 2 for C; and 0.4 and 0.7 for WP (Table 1). Note that values of C > 1 imply a shrinkage of length, which is possible in cephalopods, but not further discussed here.

The recruitment patterns differed from year to year (Fig. 2). In 1983, recruitment occurred throughout the year, with a maximum in June whereas 1984 had a marked peak in July/August. In 1985, the recruitment peak was delayed, with a maximum in September; in 1986 the maximum recruitment occurred early, from April to July. In 1987 and 1988, recruitment occurred in two pulses, with the maxima in May/July, and a second small peak in October/November.

Mortality

Table 2 presents the values of the Z/K ratio obtained using (i) independent values of Z (from length-converted catch curves) and K (from the growth equation) and (ii) with the method of Wetherall et al. (1987). Both groups

Table 1. Growth parameters estimated for *Octopus maya* from Campeche Bank. N = ELEFAN I analyses based on actual number of octopuses in the mantle length distributions. SQR(N) = analyses using square root of number of octopuses in the length distributions.

Year	K (year)	L_∞ (mm)	ω (L_∞ xK)	C	WP	ESP/ASP
			Option with (N)			
1983	1.42	231	3.28	2.0	0.2	0.747
1984	1.48	235	3.48	0	0	0.740
1985	2.35	194	4.56	1.1	0.8	0.826
1986	0.80	245	1.96	0.9	0.6	0.816
1987	1.42	237	3.36	2.0	0.5	0.605
1988	2.40	196	4.70	0	0	0.543
Mean	1.65	223	3.68	-	-	-
			Option with SQR(N)			
1983	1.11	218	2.42	0	0	0.541
1984	1.30	238	3.09	0	0	0.565
1985	1.12	237	2.65	1.4	0.7	0.671
1986	0.90	220	1.92	1.4	0.5	0.771
1987	1.20	219	2.63	2.0	0.4	0.620
1988	1.20	216	2.59	0	0	0.679
Mean	1.14	225	2.56	-	-	-

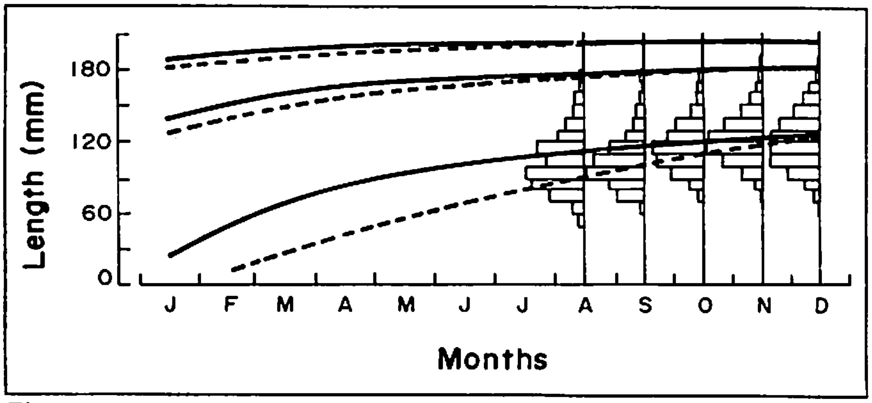

Fig. 1. *Example of the fit of von Bertalanffy growth curves to length frequency distributions of Octopus maya (1986). Solid line, seasonal growth; dashed line, non-seasonal growth. Parameters used: L_∞ = 220 mm; K = 0.9/year [with C = 1.4 and WP = 0.53 for seasonal growth].*

Table 2. Mortality estimations for *Octopus maya* on Campeche Bank, obtained with the method of Wetherall et al. (1987) and from length-converted catch curves.

Year	Catch curves Z(/year)	K(/year)	Z/K	Wetherall plot Z/K	L_c(mm)[a]
1983	2.65	1.11	2.25	2.59	78.4
1984	6.32	1.30	4.84	4.90	84.4
1985	5.84	1.12	5.23	4.73	68.0
1986	4.48	0.90	4.90	4.01	94.4
1987	4.92	1.20	4.20	3.73	95.0
1988	5.61	1.2	4.60	3.40	99.2

[a]Length from which octopus are assumed to be completely recruited or available to the gear.

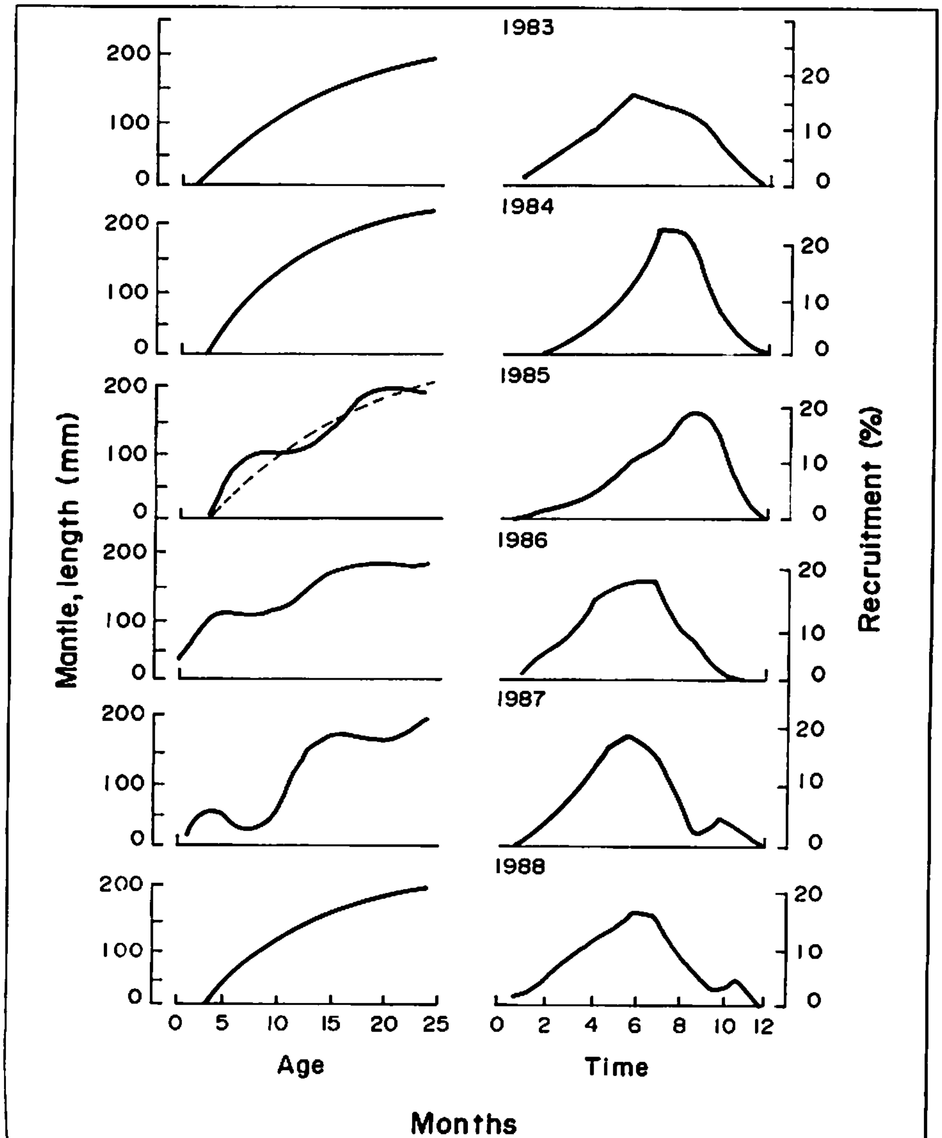

Fig. 2. *Growth curves (left) and seasonal recruitment pattern (right) for* Octopus maya, *by year, on Campeche Bank, Mexico.*

of Z/K values were compared using a Student's t-test (with $\alpha = 0.05$), and significant differences between them were found.

Growth parameters are required for the estimation of total mortality (Z), through a length-converted catch curve; here the growth parameters estimated through the square root approach were used. Values of Z ranged from 2.65 to 6.32/year, and Z/K values ranging from 2.2 to 5.2 were obtained (Table 2). Application of the Wetherall method led to Z/K estimates ranging from 2.59 to 4.9.

The estimates of K obtained here were much lower than the estimates of 3.2/year (for $L_\infty = 230$ mm) published by Solís-Ramirez and Chávez (1986), and this is probably due to the fact that the Cassie method, which they combined with Modal Class Progression Analysis, failed to identify representative cohorts. Conversely, there might be a problem with the application of ELEFAN I to octopus; which of these alternative applies cannot be resolved here.

It appears that seasonally oscillating growth occurred only during a few years, i.e., growth patterns were not the same year to year; these differences can be linked to the seasonality of recruitment, because the simultaneous analysis of both recruitment patterns and growth curves suggests a clear temporal sequence. Thus, in 1983 recruitment had its maximum in June; the growth curve for the next year, 1984, does not display seasonal oscillations. On the other hand, the maximum recruitment peak in 1984 occurred in July/August, and the growth curve for 1985 oscillates seasonally. For the next two years, maximum recruitment occurred in September for 1985 and June-July for 1986, while the growth curves displayed seasonal oscillations. The next year (1987), maximum recruitment occurred in June, and the subsequent growth curve, for 1988, did not display seasonal oscillations.

In 1987 and 1988, a small recruitment pulse occurred in October and November, respectively. In 1986, although the maximum peak of recruitment occurred in June/July, some recruitment had occurred from April on; in 1987, maximum recruitment occurred in June, but some also occurred from April on. The small recruitment peaks at the end of the year (for the 1987 and 1988 fishing seasons) are consequences of the reproduction of those individuals generated on April of the same year. According to Solís-Ramirez (1967), *O. maya* reach sexual maturity at an age of 5-6 months, and in 1987 and 1988, the octopuses hatched in April reached sexual maturity in August/September, with their youngs appearing as recruits at the end of the same year.

Conclusions

Some important aspects of the biology of *O. maya* have emerged from this. *O. maya* is a short-lived species, strongly affected by seasonal changes. Of these, the most important are those related to the timing of the reproduction and recruitment processes. When recruitment occurs early (peak in June), the growth curve for the next year will not display seasonal oscillations, because most of the octopuses will have reached the adult stage, less affected by seasonal changes, when the temperature drops. However, if recruitment occurs late, the growth curve for the next year will be strongly influenced by seasonal changes because the bulk of the population will consist of 2-3-month-old juveniles during the cold season.

This leads us to various, earlier discussions on the validity of the von Bertalanffy model when applied to cephalopods. Forsythe and Hanlon (1980), Hanlon and Forsythe (1985), Forsythe and van Heukelem (1987), and Hanlon (1987), all working in laboratories, suggested that the von Bertalanffy equation does not describe satisfactorily cephalopod growth, especially for young octopuses. However, the results presented here and the relationships between timing of recruitment and the occurrence of seasonal growth, suggest that the von Bertalanffy is adequate for cephalopods when the interactions of time at hatching and seasonal growth are considered. This confirms Pauly (1985, esp. Fig. 3), who made precisely the same point. Temperature appeared to be the most important variable affecting growth (see also Pauly 1985, Fig. 4), although this may work by impacting the food organisms of young octopuses. Further studies are clearly needed to determine the responses of the octopus growth to different environmental stimuli and their links with the dynamics of the natural population.

Regarding the mortality estimations, the values on Table 2 suggest some stability for the last four years. On the other hand, Table 2 shows two statistically different sets of Z/K values. The available information does not permit to decide which of them includes the "best" estimate, especially as the timing of recruitment changes between years. Thus again, more studies are needed on the dynamics of octopus population sizes and structure.

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