

The population dynamics of *Nemipterus marginatus* (Cuvier & Val.) off Western Kalimantan, South China Sea

D. PAULY AND P. MARTOSUBROTO*

International Center for Living Aquatic Resources Management (ICLARM), MCC P.O.
Box 1501, Makati, Metro Manila, Philippines

(Received 19 October 1979, Accepted 9 December 1979)

The following parameter values are derived for a West Kalimantan (West Borneo) stock of the threadfin bream, *Nemipterus marginatus*:

$$L_{\infty} = 24.5 \text{ cm (L.T.)}, W_{\infty} = 210 \text{ g}, K = 0.42, t = -0.41 \text{ and } M = 1.73.$$

Yield-per-recruit curves for *N. marginatus* are presented. Catch per hour of *N. marginatus* is very low, even in the area of highest density (≈ 3.5 kg/h at 45 m depth). Single-species exploitation of a stock of the type represented by *N. marginatus* appears unfeasible and the conclusion is reached that the traditional single-species approach in fish population dynamics—such as exemplified in this paper—does not help in formulating rational exploitation schemes.

I. INTRODUCTION

One of the most important problems facing those involved in the management of the demersal multi-species stocks of Southeast Asia is the problem of the effect of species interactions on the maximum sustainable yield (Pauly, 1979b). Finding a solution to this problem, however, will probably require that a large body of data be accumulated on the biology of those species which contribute most of the stocks in question.

The present paper is an account of the biology of *Nemipterus marginatus* off Western Kalimantan (Borneo), and is based on data collected during a cruise of the R/V Mutiara 4, of the Indonesian-German Demersal Fisheries Project, in the Indonesian waters of the South China Sea, in August and September 1975.

Of the 147 single-haul stations covered during this cruise, 80 were sampled for *Nemipterus marginatus* (Table I), and the data discussed here pertain only to these 80 hauls. As a group, the Nemipteridae (*Nemipterus* spp. + *Scolopsis* spp.) contributed to 6% of the total catch, and *N. marginatus* contributed to 20% of the nemipterid catch, or 1.2% of the total catch. The data presented here thus pertain to one of the most important nemipterid species in the Indonesian part of the South China Sea. The present paper updates and amplifies a preliminary analysis given, in Indonesian, by Martosubroto (1977).

II. MATERIAL AND METHODS

MATERIAL

The catch and length-frequency data were obtained by the authors during the course of a trawl survey with R/V Mutiara 4, lasting from 6 August to 29 September

*Marine Fisheries Research Institute, Jalan Krapu 12, Jakarta-Kota, Indonesia.

TABLE I. Stations sampled for *Nemipterus marginatus* off Western Kalimantan

Stations: 59-85; 85-110; 119-147; Stations sampled: 80
 Dates: Stn 59 : 25.08, 1975; Stn 60-147: 31.08 ti 16.09, 1975.

Reference to exact position, date, depth, and other data pertaining to each station: See Martosubroto & Pauly (1976).

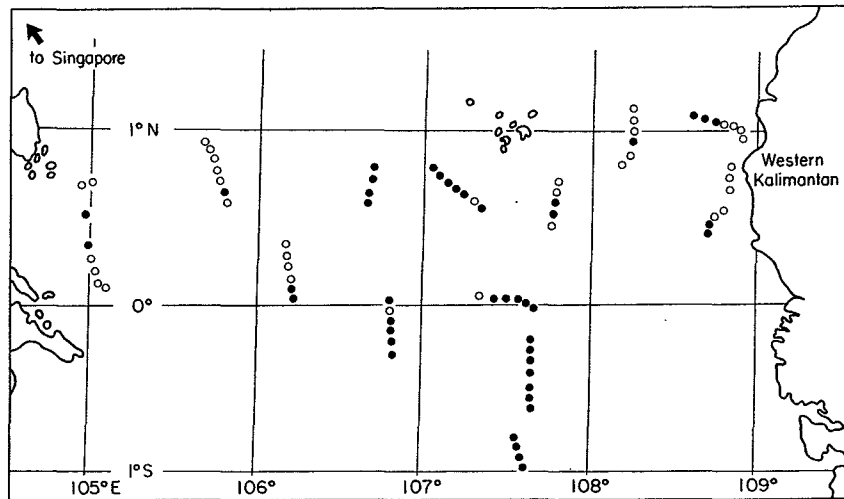


FIG. 1. Sampling area and stations. *Nemipterus marginatus* occurring in catch (●); no *N. marginatus* in catch (○).

TABLE II. Summary of length-frequency data on *Nemipterus marginatus* from Western Kalimantan

Class (cm)	N*	Cumulative %	Class (cm)	N*	Cumulative %
7.5	1	0.03	15.5	172	76.36
8.0	3	0.12	16.0	140	80.63
8.5	9	0.40	16.5	133	84.68
9.0	16	0.88	17.0	102	87.79
9.5	40	2.10	17.5	79	90.19
10.0	55	3.78	18.0	82	92.69
10.5	100	6.82	18.5	78	95.07
11.0	122	10.54	19.0	59	96.86
11.5	157	15.32	19.5	39	98.05
12.0	200	21.41	20.0	24	98.73
12.5	218	28.05	20.5	12	99.15
13.0	211	34.48	21.0	13	99.54
13.5	287	43.22	21.5	8	99.79
14.0	356	54.07	22.0	2	99.85
14.5	334	64.24	22.5	3	99.94
15.0	226	71.12	23.0	2	100.00

*Sum of 44 samples; Stations 59-147.

1975. Data on *N. marginatus*, however, were collected only from 25 August onwards, with one sample taken on 25 August and another on 31 August; all other samples being taken in September (see Table I). The positions, fishing depth and other data pertaining to these stations have been presented elsewhere (Martosubroto & Pauly, 1976). Figure 1 shows the sampling area and the location of the stations sampled for *N. marginatus*.

Each station consisted of a 60 min haul with a 'Thai-German Trawl' (see Saeger *et al.*, 1976 for specifications). At each station, the total *N. marginatus* catch has been weighed, counted and all fishes measured. (The highest catch weighed 16.5 kg and consisted of 368 fishes.) A total of 3283 fishes were measured.

Following the cruise, the preserved fishes of a sample ($n=69$) ranging from 8.2 to 22.9 cm (L.T.) and from 7.4 to 169 g (wet weight) were measured in terms of standard length (L.S.), fork length (F.L.) and total length (L.T.), and weighted to the nearest tenth of gramme.

METHODS

Length measurements are expressed—when not mentioned otherwise—in terms of total length, where the 'tip of the caudal fin' refers to the lower caudal lobe, as the upper caudal lobe in *N. marginatus* tapers off into a filament (Wongratana, 1972). This method allows for our measurements to be compared directly to those of Weber & Jothy (1977), who used the same definition of total length.

The consolidated length frequency sample obtained by pooling all 3283 fishes measured during the cruise (Table II) was separated into three normally distributed subsamples, assumed to represent year classes, by the graphical method of Cassie (1954).

The von Bertalanffy Growth Formula (VBGF) was used to describe the growth of *Nemipterus marginatus*. The VBGF, for length, has the form:

$$L_t = L_\infty (1 - e^{-K \times (t - t_0)}) \quad (1)$$

instead of an independent estimate of L_∞ , an estimate of $L(\infty)$ was obtained from L_{\max} , the size of the largest fish recorded from a given stock, using the relationship:

$$\frac{L_{\max}}{0.95} = L(\infty). \quad (2)$$

The growth parameter K was obtained from the length of the three age groups (= length at relative age), a value of $L(\infty)$ and a plot of

$$-\ln \frac{(L(\infty) - L_t)}{L(\infty)}$$

on relative age, the slope of this plot providing an estimate of K (see von Bertalanffy, 1934; Beverton & Holt, 1957: 283). The parameter t_0 , finally was estimated from empirical relationship:

$$\log(-t_0) = 0.3922 - 0.2752 \times \log L_\infty - 1.038 \times \log K \quad (3)$$

which was derived from 153 triplets of L_∞ , K and t_0 values and which—through the estimation of t_0 —allows for the attribution of an approximate absolute age to fishes whose length growth parameters (L_∞ and K) are known (Pauly, 1979a).

Natural mortality rate (M) was assumed to equal total mortality rate (Z), as the sampling area, in 1975 was virtually unfished.

Estimates of M could thus be obtained from:

$$Z = \ln \frac{N(n+1)}{N(n+2)} \quad (4)$$

where $N(n+1)$ is the number (or percentage) of fishes of relative age $n+1$ and $N(n+2)$ the

number (or percentage) of fishes of relative age $n + 2$ (see Table 5).

M was also estimated from the mean length in the catch by means of the equation:

$$Z = \frac{K \times (L_{\infty} - \bar{L})}{(\bar{L} - L_c)} \quad (5)$$

where $Z = M$, L_{∞} and K refer to equation (1) and where \bar{L} is the mean length, in the catch of all fish $> L_c$ (Beverton & Holt, 1956). L_c , finally, the mean length at first capture, was estimated from the mesh size and the Selection Factor (s.f.) by means of the relationship:

$$L_c = (\text{s.f.}) \times (\text{mesh size}), \quad (6)$$

(see Jones, 1976). The samples discussed here (including that of Weber & Jothy, 1977) were obtained with a mesh size of 4.0 cm (stretched), while Jones (1976) gives for the genus *Nemipterus* an average value of s.f. = 3.0.

Yield per recruit (Y/R) was estimated from the equation:

$$\frac{Y}{R} = F \times N_0 e^{-Mr} \times W_{\infty} \left(\frac{1}{Z} - \frac{3e^{-Kr}}{Z+K} + \frac{3e^{-2Kr}}{Z+2K} - \frac{e^{-3Kr}}{Z+3K} \right) \quad (7)$$

where W_{∞} is the asymptotic weight, F the fishing mortality, M the natural mortality, Z the total mortality ($F + M$) and $r = t_c - t_0$, t_c being the mean age at first capture (= the age corresponding to L_c).

Note that this model implies a conventional starting point at age t_0 with N_0 fishes (N_0 is here set equal to one fish).

Equation 7 is a shortened version of the model of Beverton & Holt (1957), as may be found, e.g. in Ricker (1975: 253, equation 10.21).

III. RESULTS

DISTRIBUTION

Figure 1 shows the area covered and the stations sampled for *N. marginatus*. Of 80 stations sampled, 36 (45%) did not yield any specimen of this species. The highest catch rates were obtained in deeper waters (in the 40–45 m depth range) while nearshore areas yielded no catch of *N. marginatus* (Fig. 2).

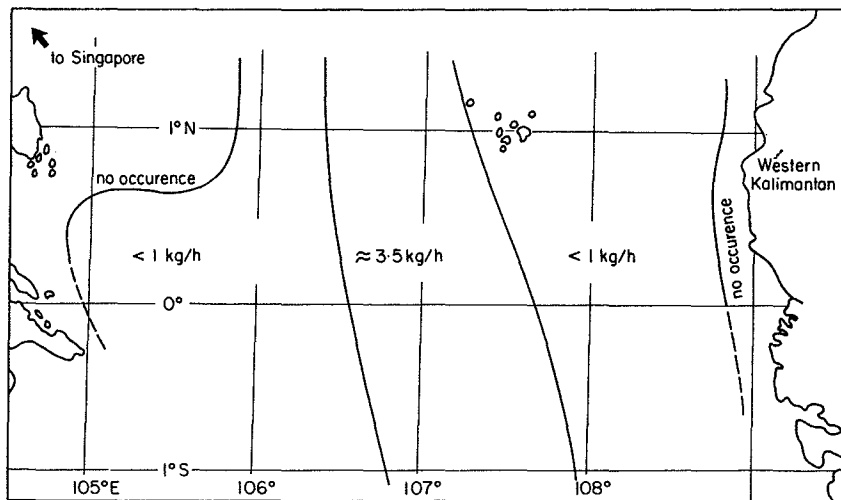
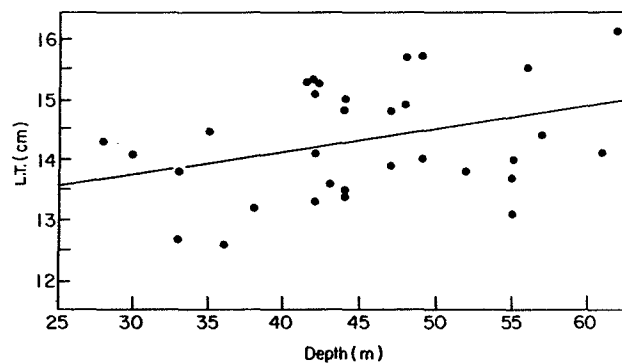
There is a significant ($P = 0.05$) correlation between mean length and fishing depth ($n = 44$, $r = 0.296$), which can be slightly improved by disconsidering those estimates of mean length based on samples with $n < 20$. In this case, the correlation coefficient increased to $r = 0.361$, with $n = 32$. This relationship between length and depth may be also expressed by the regression:

$$\text{L.T.} = 12.62 + 0.038X, \quad (8)$$

where L.T. is the length in cm and X is the fishing depth in m (Fig. 3). This confirms the findings of Weber & Jothy (1977), who found a similar relationship for *N. marginatus* off North Borneo.

GROWTH

The analysis of the consolidated length frequency sample of *N. marginatus* (Table II, Fig. 4) yields estimates of length at (relative) age which compare well with those estimated by Weber & Jothy (1977) who also used the Cassie method. Thus, Weber & Jothy (1977) identified three age groups assumed to represent year classes, with mean lengths of 9.6, 15.8 and 19.3 cm (L.T.), while we

FIG. 2. Catch rate distribution of *Nemipterus marginatus*, in kg/h.FIG. 3. Relationship between fishing depth and mean length in the catch of *Nemipterus marginatus*.

distinguished three age groups with lengths of 11.8, 14.8 and 19.0 cm (L.T.) (see Table III). The main difference between their and our estimate of length at (relative) age indeed stems from the fact that their sampling occurred mainly in the month of April, while ours was mainly in September.

With the estimates of K obtained for both stocks from the estimates of $L_{(\infty)}$ and Equation 3, it is possible to obtain estimates of t_0 (Table III) which themselves allow for the mean length of each age group to be attributed an absolute age, by converting the VBGF (Equation 1) to:

$$\frac{\ln\left(\frac{L_{\infty} - Lt}{L_{\infty}}\right)}{-K} + t_0 = t. \quad (9)$$

The ages estimated in this manner suggest that the specimen of *N. marginatus* sampled by Weber & Jothy (1977) were, on the average, in April 1972, 0.71 years (8.5 months) past their date of birth, or first and second year of life,

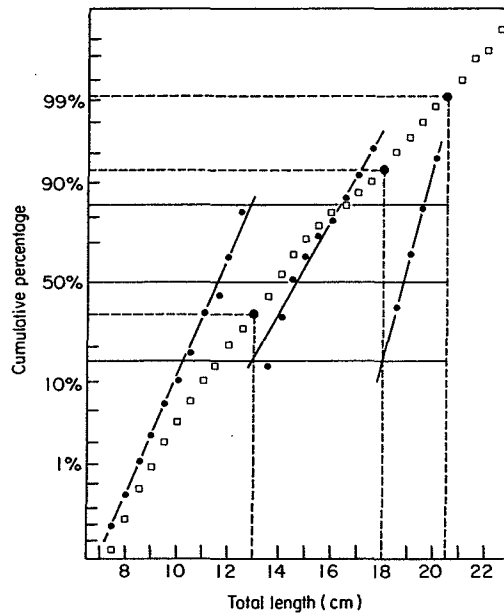


FIG. 4. Separation of the *Nemipterus marginatus* total sample into three normally distributed age groups. $n = 3283$.

respectively. On the other hand, the fish we sampled (mainly in September 1975), were on the average, 0.04 years ($\approx 1/2$ months) past their date of birth, or first and second year of life, respectively (see Table IV for computations). The fish of both stocks were thus probably hatched in August-September (Fig. 5).

LENGTH-WEIGHT CONVERSION

The sample of 69 preserved fishes mentioned above yielded the relationship:

$$W = 0.0135 \times L^{3.02}, r = 0.999. \quad (10)$$

This relationship also provided an excellent fit to the mean weights and lengths derived from the fresh samples, and may therefore be used to convert length to weight in live fishes.

It will be noted that the exponent of the length/weight relationship is very close to 3, for which reason this relationship may be satisfactorily expressed by means of the condition factor (C.F.) where:

$$\text{C.F.} = \frac{W \times 100}{L^3}. \quad (11)$$

The mean C.F. for the above mentioned sample of *N. marginatus* is 1.43. The weight growth curve for the West Kalimantan stock may thus be expressed as:

$$W_t = 210 (1 - e^{-0.42(t+0.41)})^3. \quad (12)$$

TABLE III. Length at-age data and growth parameters of *Nemipterus marginatus* off Borneo

Age (years)	A L.T. (cm)	B L.T. (cm)
n	9.6*	11.75
$n+1$	15.8*	14.85
$n+2$	19.3*	19.00
L_{\max}	27.0*	23.5
$L(\infty)\dagger$	28.5	24.5
K	0.36	0.42
$t_0\ddagger$	-0.47	-0.41

A Off Northern Borneo (Sabah & Sarawak).
 B Off Western Borneo (West Kalimantan, Indonesia), based on present data.

*In Weber & Jothy (1977).

†Based on Equation 2.

‡Based on Equation 3.

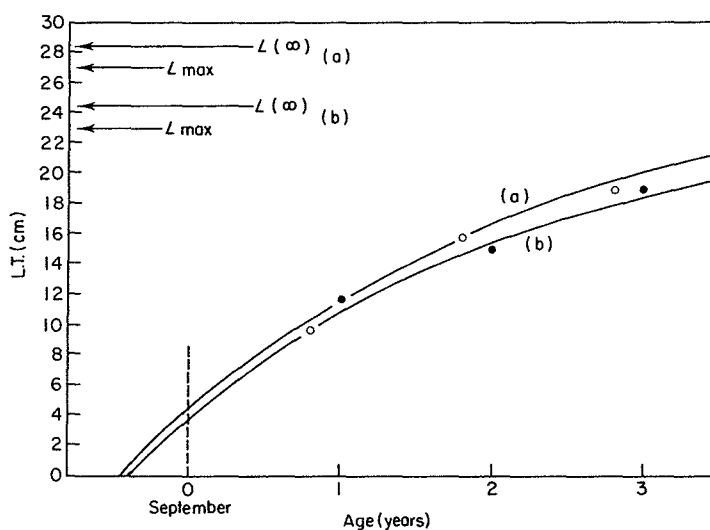


FIG. 5. Growth in length in two stocks of *Nemipterus marginatus*. (a) Northern Borneo (O); (b) Western Borneo (●).

CONVERSIONS BETWEEN DIFFERENT LENGTH MEASUREMENTS

The different length measurements of the fishes of the preserved sample allowed for the following regressions to be calculated (with $n = 69$, all lengths in cm):

$$L.S. = 0.204 + 0.794 \times L.T., r = 0.992 \quad (13)$$

$$\text{and } L.F. = 0.513 + 0.855 \times L.T., r = 0.994. \quad (14)$$

It is recalled that these regressions, which may help in comparative studies of different of *N. marginatus*, apply to L.T. values ranging from 8.2 to 22.9 cm.

TABLE IV. Data and method for the estimation of an approximate birthdate in two stocks of *Nemipterus marginatus* off Borneo

Relative age	Length	(A) North Borneo Absolute age (years)*	Length	(B) West Kalimantan Absolute age (years)*
n	9.6	0 year + 0.67	11.75	1 year + 0.15
$n+1$	15.8	1 year + 0.78	14.85	2 years - 0.19
$n+2$	19.3	2 years + 0.67	19.00	3 years + 0.15
	Mean fractional age	{ + 0.71 (years) 8.5 (months)	Mean fractional age	{ + 0.04 (years) ≈ 0.5 (months)
Mean time of capture		mid-April		mid-September
Approximate birthdate		begin of August		begin of September

*Based on Equation 9 and the growth parameters in Table III.

TABLE V. Estimate of M in two stocks of *N. marginatus* off Borneo

	(A) North Borneo	(B) West Kalimantan
\bar{L}	17.2	15.1
$N(n+1)$	1469*	58%
$N(n+2)$	310*	6.5%
M^\dagger	0.72	1.27
M^\ddagger	1.56*	2.19
\bar{M}	1.14	1.73

*In Weber & Jothy (1977).

†Based on Equation 5.

‡Based on Equation 4.

NATURAL MORTALITY

Table V gives the various values of natural mortality estimated for *N. marginatus*. Quite clearly, the estimates obtained from Equation 4 are very high compared to those estimated from Equation 5, and possibly too high for fishes which may reach, in nature, an age of 4 years or perhaps more (see Fig. 5).

The value of M used for estimating the yield-per-recruit was obtained by averaging, for the stock of *Nemipterus marginatus* off Western Kalimantan the values of M obtained by using the two methods, which resulted in a mean value of $\bar{M} = 1.73$ (see Table V).

YIELD-PER-RECRUIT

Figure 6 gives the yield-per-recruit in grammes for two ages at first capture ($t_c = 0.26$ and 1.2 years), roughly corresponding to the size selected by meshes of

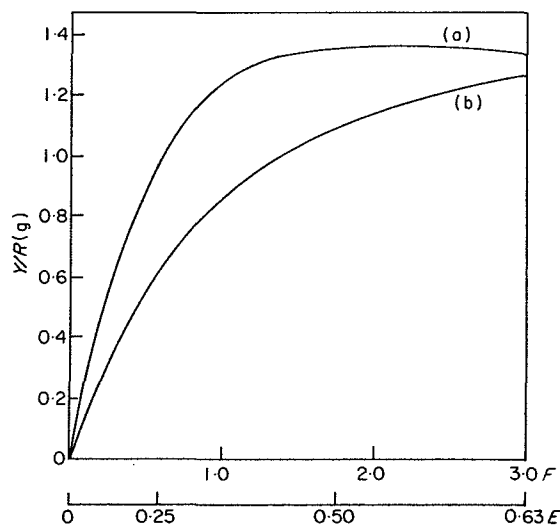


FIG. 6. Yield-per-recruit in the Western Kalimantan stock of *Nemipterus marginatus*. (a) $t_c = 0.26$ (≈ 2 cm meshes); (b) $t_c = 1.2$ (≈ 4 cm meshes). F , fishing mortality; E , exploitation rate.

2 and 4 cm, respectively. The range of fishing mortality covers values of $F=0$ to $F=3$, corresponding to exploitation rates $\left(E = \frac{F}{F+M}\right)$ ranging from $E=0$ to $E=0.63$. It will be noted that the smaller meshes produces a higher yield per recruit for all values of F considered here.

IV. DISCUSSION

The present investigation on the biology and population dynamics of the threadfin bream *Nemipterus marginatus* has two aspects.

The most obvious aspect is that we present data on the growth and mortality of a tropical demersal fish such that yield-per-recruit could be estimated; also, we show that it is relatively easy to obtain such data. This could be done, however, only by making the assumption that, in *Nemipterus marginatus* $L_{\infty} \approx L_{\max}$ (see Equation 2); this assumption allowed for a value of K to be derived from limited length at (relative) age and subsequently for the derivation of values of t_0 and M .

One of us (Pauly, 1979a) has demonstrated that the assumption that $L_{\infty} \approx L_{\max}$ generally applies in smaller fishes (say with $L_{\max} < 50$ cm) and has given reasons for this limitation. The approach used here to generate growth parameters from limited data has been used previously (Pauly, 1978a) to generate growth parameters in many fish species, inclusive of several *Nemipterus* species, and the parameter values so obtained were in accordance with those obtained from *Nemipterus* species which had been aged by means of a classical method (reading scales) (Pauly, 1978: 83–84). Our value of $K=0.42$ thus appears valid.

As a whole *N. marginatus* (as most other nemipterid species) is extremely slow-growing, needing more than three years to reach a weight of 100 g. This contrasts with the widely-held assumption that tropical fishes are generally 'fast-growing'. This slow growth, combined with the high value of our estimate of natural mortality ($\bar{M} = 1.73$) results in the highest yield-per-recruit being obtained with rather small meshes. These findings are a direct consequence of the high value of the ratio $M/K (= 4.1)$, which is outside of the range encountered in most tropical fishes, and in nemipterids in particular (Pauly, 1978b, Krishnamoorthi, 1976). Possibly, the value of M is biased upward, i.e. there has been an increase in recruitment in the years immediately preceding the time when the samples were taken.

The yield-per-recruit analysis also brings us to the second aspect of the present contribution: We have emphasized in the Introduction that the Nemipteridae are, in the South China Sea, one of the most abundant families, and that *N. marginatus* was, during our cruise, the most abundant nemipterid species. Still, *N. marginatus* contributed only to 1.2% of the total catch, with catch rates of about 3.5 kg/h in those areas where its density was highest. Obviously, there cannot be any fishery based exclusively on *N. marginatus* (even if it were technically possible to select for this species). Thus, we find that the yield-per-recruit analysis in Fig. 6 does not really tell us anything about the most appropriate rate of exploitation or mesh size that should be used in conjunction with this stock.

The stock of *N. marginatus* investigated here, in reality can be exploited only together with the other demersal species it is associated with, and the best fishing strategy (amount of effort, mesh size, type of gear, etc) will have to be determined

on the basis of a model that takes into account both the existence of a vast number of species on the fishing grounds and the biological interactions (predation, competition) taking place between them (Pope, 1979; Pauly, 1979b).

References

- Bertalanffy, L. von (1934). Untersuchungen über die Gesetzlichkeit des Wachstums. I Allgemeine Grundlagen der Theorie, mathematische und physiologische Gesetzmäßigkeiten des Wachstums bei Wassertieren. *Wilhelm Roux Arch. EntwMech.* **131**, 613–652.
- Beverton, R. J. H. & Holt, S. J. (1956). A review of methods for estimating mortality rates in fish populations, with special references to sources of bias in catch sampling. *Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer* **140**, 67–83.
- Beverton, R. J. H. & Holt, S. J. (1957). On the dynamics of exploited fish populations. *Fishery Invest., Lond.* (2) **19**, 533 pp.
- Cassie, R. M. (1954). Some uses of probability papers in the analysis of size frequency distributions. *Aust. J. mar. Freshwat. Res.* **5**, 513–522.
- Jones, R. (1957). A much simplified version of the fish yield equation. *Lisbon Joint Meeting of Intern. Comm. Northwest Atl. Fish. Intern. Counc. Explor. Sea and FAO, Doc. No. P21*, 8 pp.
- Jones, R. (1976). Mesh regulations in the demersal fisheries of the South China Sea area. *SCS/76/WP/34*, 75 pp.
- Krishnamoorthi, B. (1976). A note on mortality rates and yield per recruit in *Nemipterus japonicus* (Bloch). *Indian J. Fish.* **23**, 252–256.
- Martosubroto, P. (1977). [Fishery potential of threadfin bream (Fam. Nemipteridae) and some biological aspect of *Nemipterus marginatus* (Cuvier & Valenciennes) in South China Sea.] In Indonesian. Paper presented to the 5th Biology Seminar in Malang, July, 1977, Indonesia. 17 pp. Mimeographed.
- Martosubroto, P. & Pauly, D. (1976). R/V Mutiara 4 survey data, November 1974 to July 1976. *Contr. Demersal Fish. Project, No. 2*, 136 pp. Jakarta: Marine Fisheries Research Institute (L.P.P.L.).
- Pauly, D. (1978a). A preliminary compilation of fish length growth parameters. *Ber. Inst. f. Meereskunde (Kiel)* No. **55**, 200 pp.
- Pauly, D. (1978b). A discussion of the potential use in fish population dynamics of the interrelationships between natural mortality, growth parameters and mean environmental temperature in 122 fish stocks. *I.C.E.S. CM 1978/G:21 Demersal Fish Ctee*, 36 pp.
- Pauly, D. (1979a). Gill size and temperature as governing factors in fish growth: a generalization of von Bertalanffy's growth formula. *Berichte Inst. f. Meereskunde (Kiel)* No. **63**, 156 pp.
- Pauly, D. (1979b). Theory and management of tropical multispecies stocks: a review with emphasis on the Southeast Asian demersal fisheries. (ICLARM) *Stud. Rev.*, **1**, 35 pp. International Center for Living Aquatic Resources Management, Manila.
- Pope, J. (1979). Stock assessment in multispecies fisheries, with special reference to the trawl fishery in the Gulf of Thailand. *SCS/DEV/79/19*, 106 pp.
- Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bull. Fish. Res. Bd Can.* **191**, 382 pp.
- Saeger, J., Martosubroto, P. & Pauly, D. (1976). First report of the Indonesian-German demersal fisheries project (Results of a trawl survey in the Sunda Shelf area). *Contrib. Demersal Fish. Project, No. 1*, 1–46. Jakarta: Marine Fisheries Research Institute (L.P.P.L.).
- Weber, W. & Jothy, A. (1977). Observations on the fish *Nemipterus* spp (Family: Nemipteridae) in the coastal waters of East Malaysia. *Arch. FischWiss* **28**, 109–122.
- Wongratana, T. (1972). Identification of *Nemipterus* in Thailand. *The Kuroshio II. Proceedings of the 2nd CSK Symposium* (K. Sugawara, ed.), pp. 465–487. Tokyo: Saikon Publishing.

