http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet

Asian Network for Scientific Information

308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (19): 3284-3294, 2007
ISSN 1028-8880

Biology and Population Dynamics of the Goby *Pseudapocryptes elongatus* in the Coastal Mud Flat Areas of the Mekong Delta, Vietnam

[1,2]T.D. Dinh, [1]M.A. Ambak, [1]A. Hassan and [2]N.T. Phuong
[1]Faculty of Agrotechnology and Food Science,
University College of Science and Technology Malaysia,
Menggabang Telipot, 21030 Kuala Terengganu, Malaysia
[2]College of Aquaculture and Fisheries, Campus 2, Cantho University,
3/2 Street, Cantho City, Vietnam

Abstract: This study describe the reproductive biological characteristics and population parameters of the goby, *Pseudapocryptes elongatus* (Cuvier, 1816), in the coastal mud flat areas of the Mekong Delta, Vietnam. A total of 1058 specimens was collected from January 2004 to June 2005 and results showed that the breeding season occurred with two spawning peaks in July and October. Length at first maturity (L_m) was 15.4 and 16.3 cm for females and males, respectively. The batch fecundity estimates ranged from 2,652 to 29,406 hydrated oocytes per ovary in the fish ranging from 12.8 to 22.4 cm TL. Length frequency data of the goby ranging from 9.0 to 24.0 cm TL were analyzed using the FiSAT II software. The von Bertalanffy growth parameters were determined as L_8 = 25.9 cm, K = 0.66 year^{-1} and t_o = - 0.26 year^{-1}. The longevity (t_{max}) of the goby was estimated to be 4.55 years. There were two recruitment peaks with very different magnitudes and the means of these two peaks were separated by an interval of 5 months. Length at first capture (L_c) was 10.05 cm, the instantaneous fishing mortality rate (F = 1.38 year^{-1}) and natural mortality rate (M = 1.46 year^{-1}) accounted for 49 and 51% of the total mortality (Z = 2.84 year^{-1}), respectively. Relative yield-per-recruit and biomass-per-recruit analyses gave E_{max} = 0.65, $E_{0.1}$= 0.55 and $E_{0.5}$ = 0.33. Results show that the fish stock is subjected to growth overexploitation.

Key words: Breeding season, batch fecundity, fish population, growth parameter

INTRODUCTION

The goby, *Pseudapocryptes elongatus*, is distributed in the Indo-Pacific region and is common in the Mekong Delta, Vietnam (Weber and De Beaufort, 1953; Mohsin and Ambak, 1996; Rainboth, 1996). This species resides in muddy localities and also in burrows situated in mud flats of the estuarine areas (Murdy, 1989; Clayton, 1993). In the Mekong Delta, the highest number of gobiid species is found in the estuarine areas (Matics, 2000), in which *P. elongatus* is a commercially important species for food, especially in Japan, Taiwan and Vietnam (Ip *et al.*, 1990). For that reason, this species is presently cultured in semi-intensive and intensive farming system; however, the seeds are collected only from the wild and not enough for aquaculture.

The Gobiidae consists mainly of small, benthic fishes that occupy estuarine habitats in tropical and subtropical waters (Chotkowski *et al.*, 1999). The estuarine habitats are ecologically dynamic and productive areas used by many estuarine-dependent species for reproduction (Blaber *et al.*, 1995). Many of fishes in tropical estuaries spawn and complete their life cycle within the estuarine environment (Blaber, 2000). Nearly all gobies produce demersal eggs and highly variable number of spawnings per season (Miller, 1984). Despite the fact that the gobies are the largest family of fishes, almost nothing is known of the reproduction of most species (Blaber, 2000).

The goby *P. elongatus* has been studied on the ecology (Das, 1933, 1934; Cees *et al.*, 1995), food habits and feeding apparatus (Cees *et al.*, 1995), morphology (Amrendra and Singh, 1989) and length-weight relationship (Khaironizam and Norma-Rashid, 2002). However, there is no published work on the fish population dynamics. Only one study on reproductive biology of the goby in Gangetic Delta reported by Hora (1936), but the author had not given enough evidence concerning their statements. Therefore, this study was

Corresponding Author: T.D. Dinh, College of Aquaculture and Fisheries, Campus 2, Cantho University, 3/2 Street, Cantho City, Vietnam Tel: 84-71-831587 Fax: 84-71-830247

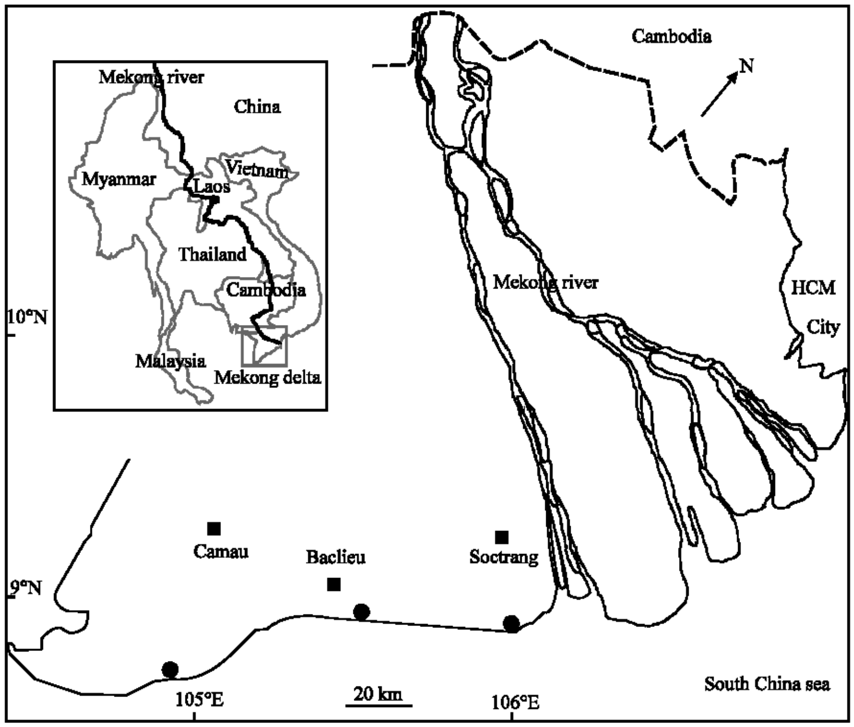

Fig. 1: The map showing three sampling sites (●) along the southeast coast of the Mekong Delta, South of Vietnam

carried out to determine the population parameters and reproductive biological characteristics of *P. elongatus* in the coastal mud flat areas of the Mekong Delta (Fig. 1).

MATERIALS AND METHODS

The fish specimens were monthly collected from January 2004 to June 2005. A total of 1058 *P. elongatus* specimens were measured to the nearest mm for total length (TL) and 0.01 g for body (BW), visceral (VW), liver (LW) and gonad weight (GW). The gonad development was classified into six stages according to the scale of maturity proposed by Vesey and Langford (1985) for *Gobius niger*. Gonadosomatic index (GSI) and hepatosomatic index (HSI) were determined as GSI = [GW/(BW–VW)]*100 and HSI = [LW/(BW-VW)]*100. Based on the fraction of mature specimens per length class, the maturity curve was estimated adjusting the simple logistic model (Zar, 1999) expressed by;

$$P=\frac{1}{1+\exp[-(\beta_0+\beta_1 L)]}$$

where, P is the proportion of mature specimens at length class L, β_0 and β_1 are model parameters. Then, the length of fish at which 50% of fish attain sexual maturity (p = 0.5) was determined to be $L_m = -\beta_0/\beta_1$ for both sexes. The whole mature ovary was placed in Gilson's fluid and periodically shaken to release oocytes from the ovarian tissue. The batch fecundity (F) was estimated as a number of hydrated oocytes in each ovary using the volumetric sub-sampling method (Bagenal and Braum, 1978): F = (V/V') n; where, V is a volume of sample, V' is a volume of sub-sample and n is a number of hydrated oocytes in sub-sample. The relationship between the batch fecundity (F) and total length (TL) was described using simple standard regression. A power model was fitted to the relationship of F and TL.

On the other work, length frequency data of the goby were also monthly collected from the fixed-bag net with codend of 15 mm mesh size. The probabilities of capture for the goby were determined using the cover codend with fine mesh size for correcting the length frequency data (Pauly, 1987). The data were analyzed using FiSAT II software for estimation the population parameters (Gayanilo *et al*., 1996, 2006). The Beverton and Holt length-based Z-equation is expressed as the linear regression equation; $\bar{L} = L'a + bL$ where, L' is cut off length, i.e., a length not smaller than the smallest length of fish fully represented in catch samples, $\bar{L}$ is mean of all fish ≥ L' and $\bar{L} = (L_\infty + L') / [(1+ (Z/K)]$. From the linear regression equation, the preliminary asymptotic length (L_∞) was calculated as (a/b) and Z/K as-(1 + b)/b (Powell, 1979; Wetherall, 1986; Pauly and Soriano, 1986).

The ELEFAN procedure contained in the FiSAT II was used to arrange and restructure the corrected length frequency data. Then, they were fitted the von Bertalanffy growth function: $L_t = L_\infty\{1 - \exp[-K(t-t_0)]\}$; where, L_t is a mean length at age t (year), L_∞ is asymptotic length, K is growth coefficient and t_0 is the hypothetical starting time at zero length (Pauly and Gaschutz, 1979). The age at length zero (t_0) was obtained using Pauly's (1979) empirical equation as follows: $\log(-t_0) = -0.392-0.275\times\log L_\infty-1.038\times\log K$. For comparison of the von Bertalanffy growth parameters, the index of overall growth performance was calculated from the formula given by Pauly and Munro (1984): $\Phi' = \log K+2\times\log L_\infty$. The longevity ($t_{max}$) was calculated using Taylor (1958) equation: $t_{max} = 3/K$.

Total mortality rate (Z) was determined using the length-converted catch curve (Pauly, 1990; Pauly *et al.*, 1995) and mean length method (Beverton and Holt, 1957). The natural mortality rate (M) was estimated using the empirical model of Pauly (1980): $\log M = -0.0066-0.279\times\log L_\infty+0.6543\times\log K + 0.463\times\log T$; where, L_∞ is expressed in cm (TL) and T is the mean annual surface water temperature (in °C) which was monthly measured using a mercury thermometer; it ranged from 28.5 to 31.5°C (29.8±0.86). The attainment of reasonable estimates of Z and M could lead to an accurate estimate of fishing mortality (F) based on the equation F = Z-M. The exploitation ratio (E) was then defined as E = F/Z (Ricker, 1975). The method of Pauly (1987) was also used to analyze the probability of capture for each size class using length-converted catch curve. The seasonal recruitment pattern of the fish species was reconstructed using the entire restructured length-frequency data set. This involved projecting backward, along a trajectory described by the computed von Bertalanffy growth function. Then using the maximum likelihood approach, the Gaussian distribution was fitted to the back-projected data through NORMSEP procedure (Hasselblad, 1966).

The yield per recruit model (Beverton and Holt, 1957) is a principal steady state model that describes the state of stock and the yield in a situation when fishing pattern has been the same for a long time so that all fish are vulnerable to capture after recruitment (Sparre *et al.*, 1989). The model, as modified by Pauly and Soriano (1986), was used to predict the relative yield-per-recruit (Y'/R) and biomass-per-recruit (B'/R) of the goby to the fishery as follows:

$$Y'/R = EU^{M/K}\{1-[3U/(1+m)] -[3U^2/(1+2m)]-[U^3/(1+3m)]\}$$

and

$$B'/R = (Y'/R)/F$$

where, $U = 1-(L_c/L_\infty)$ is the fraction of growth to be completed by this species after entry into the exploitation phase,

$$m = \frac{(1-E)}{(M/K)} = K/Z$$

The exploitation ratio (E) was compared with: i) the exploitation ratio which produces maximum yield (E_{max}), ii) the exploitation ratio at which the marginal increase of Y'/R is 10% ($E_{0.1}$) and iii) the exploitation ratio at which the stock is reduced to 50% ($E_{0.5}$). The yield isopleths diagram was used to assess the impact on yield created by changes of exploitation ratio (E) and the ratio of length at first capture to asymptotic length (L_c/L_∞).

RESULTS

A total of 1058 specimens (479 females, 461 males and 118 juveniles) of *P. elongatus* was collected from January 2004 to June 2005. This gave the female: male ratio of 1.00: 0.96 which was not significantly different between females and males ($\chi^2 = 0.345$, $p > 0.05$). Results obtained from the monthly GSI values indicated that the GSI of both female and male fish increased during May-December (Fig. 2). The GSI of females reached the highest average in July; it dropped in August-September, increased again in October, then dropped again in November-December and remained low until April. The similar pattern of GSI was also found in males; however, the highest values of GSI were determined in July and November. Furthermore, ovaries of the goby were seen to be developing (Stage II) in February, maturing (Stage III) and mature (Stage IV) in April and become dominant in June (Fig. 3). No females with running (Stage V) and spent (Stage VI) ovaries were found. Meanwhile, the maturing (Stage III) and matured (Stage IV) testes appeared in April and May, respectively. The highest percentage of mature testis was found in June (Fig. 4). On the other work, results showed that the HSI values of females were higher than that of males; however, the HSI of both sexes followed the same pattern (Fig. 5). HSI of females decreased during June-August then increased slightly in September; it decreased again and reached the lowest value in October, then increased in November. Meanwhile, HSI of male decreased during May-August and remained low until October and then increased again in November. The results obtained from the fluctuations

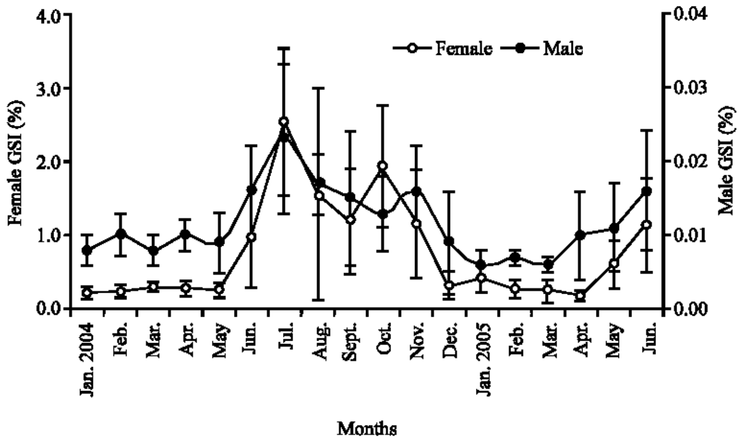

Fig. 2: Seasonal variations in gonadalsomatic index (GSI) of female and male *Pseudapocryptes elongatus* in the Mekong Delta

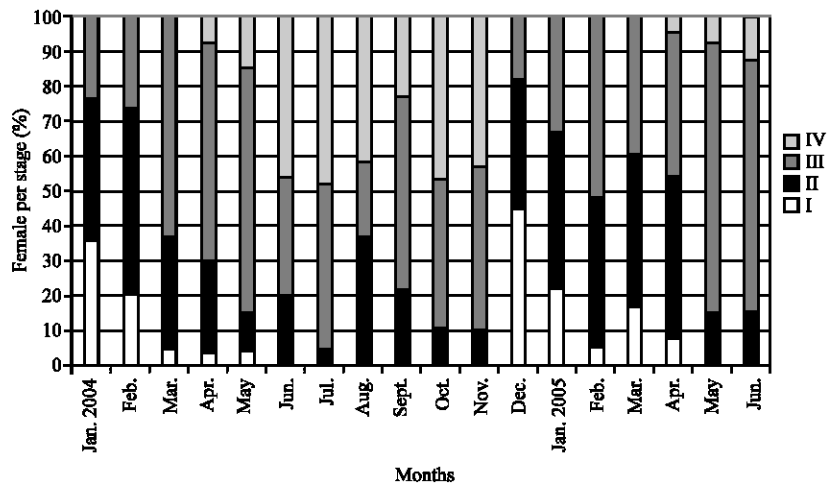

Fig. 3: Seasonal change in gonad stage composition of female *Pseudapocryptes elongatus*

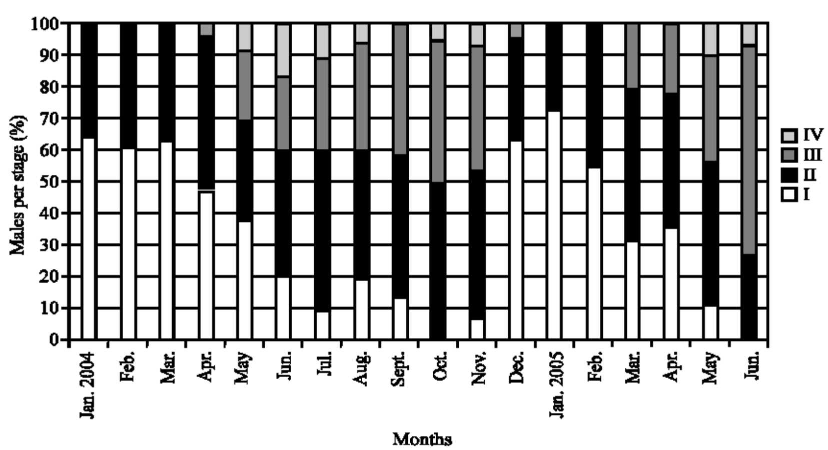

Fig. 4: Seasonal change in gonad stage composition of male *Pseudapocryptes elongatus*

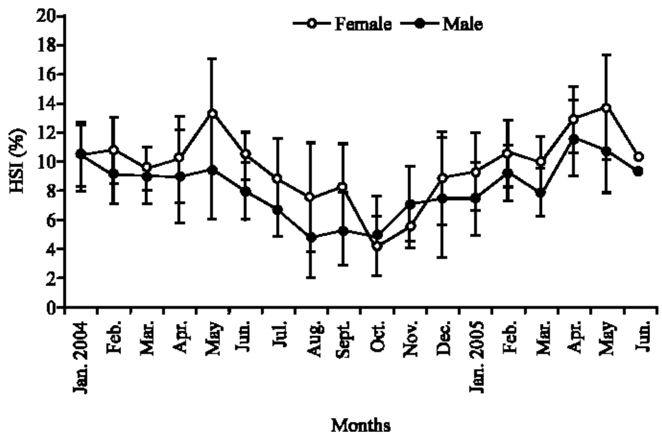

Fig. 5: Seasonal variations in hepatosomatic index (*HSI*) of female and male *Pseudapocryptes elongatus* in the Mekong Delta

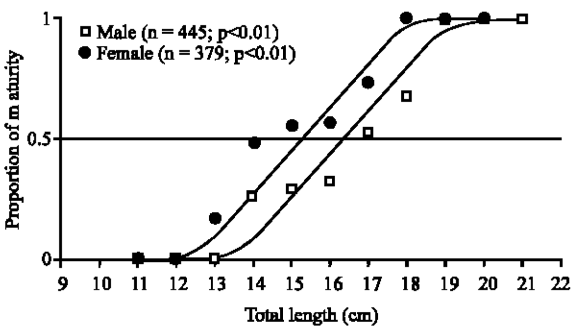

Fig. 6: Proportion of mature *Pseudapocryptes elongatus* by 1 cm total length intervals, fitted to a logistic function, L_m = 15.4 cm (n = 379; p < 0.01) for females and L_m = 16.3 cm (n = 445; p < 0.01) for males

of GSI and HSI showed that the breeding season of *P. elongatus* occur with two spawning peaks in July and October. There was marked reduction in liver size during the spawning season.

For determining length at first maturity (L_m), the proportions of maturity for 379 female and 445 male specimens were obtained. Then, the model parameters were determined as β_0 = -125.35, β_1 = 8.14 (p<0.01) for females; and β_0 = -130.05, β_1 = 7.96 (p<0.01) for males. Thus, the length at first maturity (L_m) was obtained as 15.4 and 16.3 cm for females and males, respectively (Fig. 6). The batch fecundity estimates ranged from 2,652 to 29,406 hydrated oocytes per ovary in the fish specimens ranged from 12.8 to 22.4 cm TL. The mean fecundity was 15,608 (SE = 2,478) and the mean total length was 17.9 cm. The relationship between total length (TL) and batch fecundity (F) was $F = 0.1517*TL^{3.9757}$ (R^2 = 0.727; n = 48) (Fig. 7), in which TL in cm.

A total of 9,435 fish specimens ranged from 9 to 24 cm total length was measured for length frequency data over a period of 18 consecutive months. The length frequency data were corrected using probabilities of capture for the goby (Table 1). The corrected length frequency data were analyzed using Powell-Wetherall procedure and gave an initial L_∞ of 24.86 cm and Z/K of 3.214. The initial L_∞ was fitted into ELEFAN I to determine the optimized von Bertalanffy growth curve with the following parameters: L_∞ = 25.9 cm, K = 0.66 year^{-1} and t_0 = - 0.26 year (Fig. 8).

Table 1: Probabilities of capture for *P. elongatus* in the fixed-bag net with 15 mm mesh size codend

Length class (cm)	Probability of capture
9-10	0.25
10-11	0.21
11-12	0.29
12-13	0.37
13-14	0.38
14-15	0.52
15-16	0.74
16-17	0.90
17-18	0.89
18-19	0.95
19-20	1.00
20-21	1.00
21-22	1.00
22-23	1.00

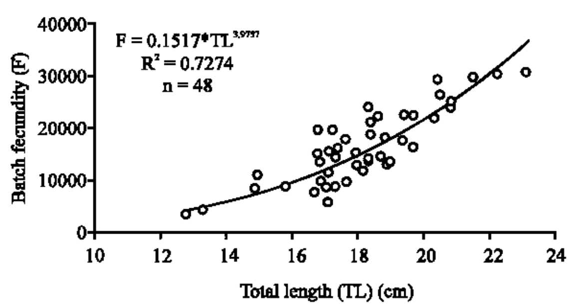

Fig. 7: The relationship between total length (TL) and batch fecundity (F) of *Pseudapocryptes elongatus* in the Mekong Delta

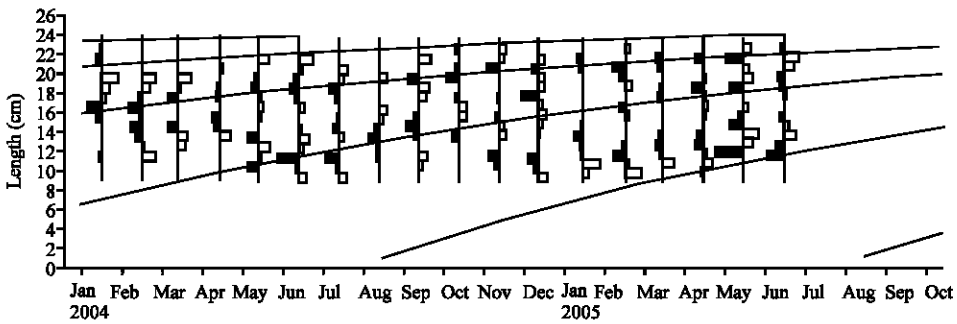

Fig. 8: The von Bertalanffy growth curve of *Pseudapocryptes elongatus* superimposed over reconstructed length frequency data (n = 9,435) collected in the Mekong Delta

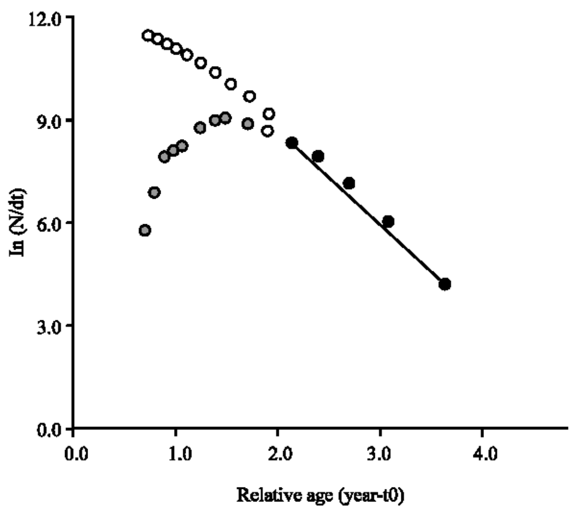

Fig. 9: The length converted catch curve for *Pseudapocryptes elongatus*. Regression equation: Y = 14.58-2.84X, r = 0.99, n = 5 (●: Points used; ○ Points not used)

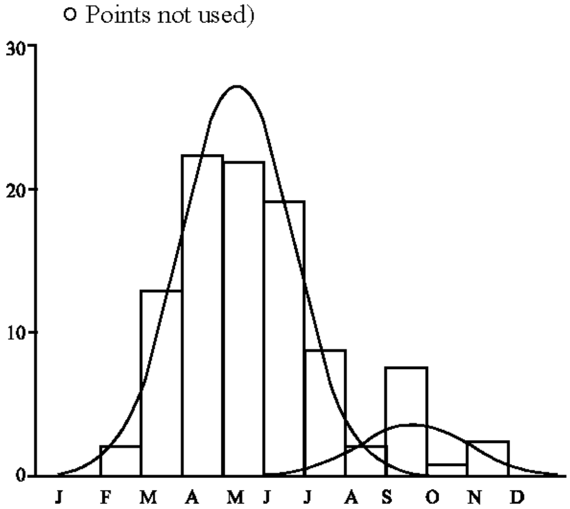

Fig. 10: Recruitment pattern of *Pseudapocryptes elongatus* in the coastal mud flat areas of the Mekong Delta estimated from length frequency data obtained during January 2004 to June 2005

Table 2: Mean length at age of the goby *P. elongatus* obtained from length frequency data and otolith readings

	Mean length (cm)		
Age class	Length frequency data	Otolith reading	Mean
1^+	14.6	13.7	141.5
2^+	20.1	18.5	193.0
3^+	22.9	20.5	217.0
4^+	24.5	21.4	228.5

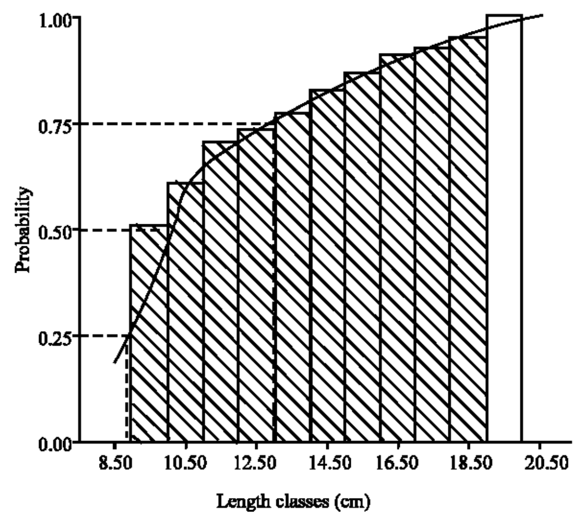

Fig. 11: The probability of capture of each length class of *Pseudapocryptes elongatus* (L_{25} = 8.88, L_{50} = 10.05, L_{75} = 12.9 cm) by using fixed-bag net with codend of 15 mm mesh size

The growth performance index and longevity were determined as Φ' = 2.65 and t_{max} = 4.28 year, respectively. Total mortality based on the length converted catch curve (Fig. 9) gave a value of Z = 2.84 year^{-1} (intercept: α = 14.58, slope: b = -2.84, r = 0.99, n = 5, confidence interval of Z: 2.17-3.51 year^{-1}). Furthermore, the total mortality (Z) was also estimated using the Beverton and Holt (1957) method The mean length for age was determined using von Bertalanffy growth functions (Table 2) which were obtained from the length frequency

Table 3: The von Bertalanffy growth parameters (L_∞ and K) and growth-performance index (Φ') for various gobiid species

Species	Φ'	L_∞ (cm)	K (year^{-1})	Source
Gobius niger (male)	2.10	11.70	0.91	Vesey and Langford (1985)
Gobius niger (female)	2.32	15.10	0.91	Vesey and Langford (1985)
Gobio gobio	2.05	10.60	0.99	Bowker (1996)
Periophthulmus papilio	2.28	19.39	0.51	Etim *et al.* (1996)
Perriophthalmus barbarus	2.41	21.60	0.55	Etim *et al.* (2002)
Pseudapoctyptes elongatus	2.65	25.90	0.66	The present study

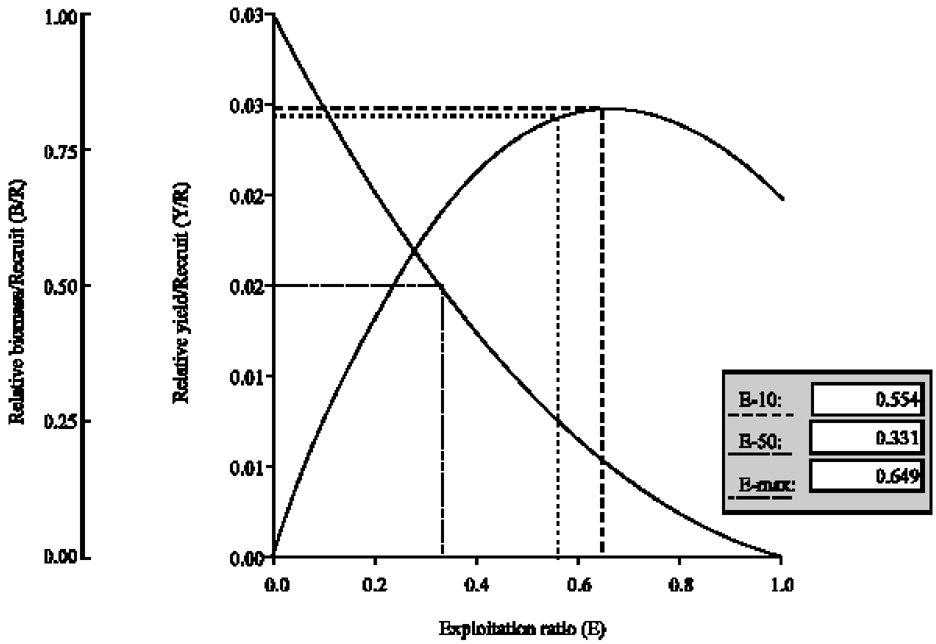

Fig. 12: The relative yield-per-recruit and relative biomass-per-recruit for *Pseudapocryptes elongatus* using the knife-edge procedure ($E_{0.5}$ = 0.33, $E_{0.1}$ = 0.55, E_{max} = 0.65)

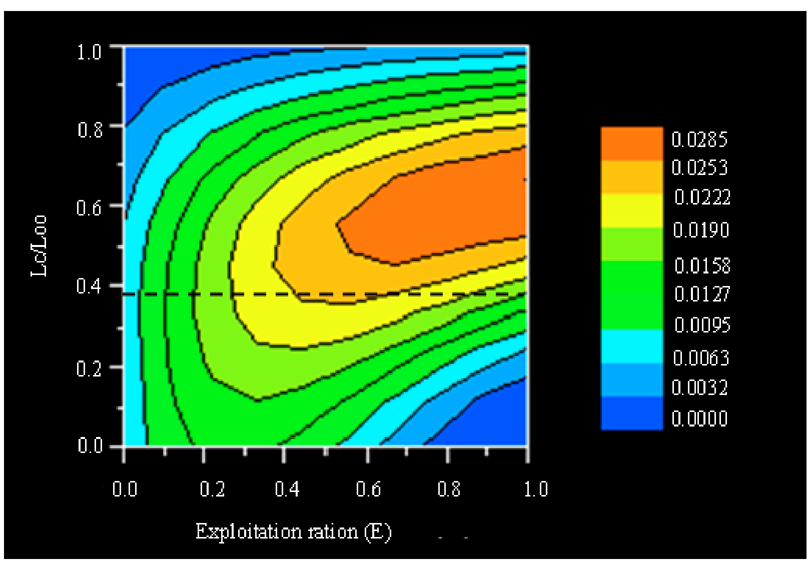

Fig. 13: The yield isopleths for *Pseudapocryptes elongatus*. The yield contours predict the response of relative yield-per-recruit of fish to changes in L_c and E. The dotted link is the actual computed critical ratio L_c / L_∞= 0.39

data and from otolith reading (Dinh *et al*., 2006). In this method, very small fish (1^+ age class) were excluded from the analysis because they were not fully recruited to the fishery. In addition, because the very old fish (4^+ age class) approach the asymptotic length, their growth in length with time becomes uncertain. Therefore, the total mortality (Z) was obtained a value of 2.48 $year^{-1}$. The natural mortality and fishing mortality rates were determined as M = 1.46 $year^{-1}$ and F = 1.38 $year^{-1}$, respectively; thus, the exploitation ratio was obtained as E = 0.49. There was two recruitment peaks with very different magnitudes and the means of two recruitment pulses were separated by an interval of 5 months (Fig. 10). The analysis of probability of capture showed that the length at first capture (L_c or L_{50}) for the goby was 10.05 cm (Fig. 11). The analyses of relative yield-per-recruit and biomass-per-recruit with the assumptions of knife-edge selection, that only fish of lengths $\geq L_c$ were recruited by the gear, gave the summary statistics as follows: E_{max} = 0.65, $E_{0.1}$ = 0.55 and $E_{0.5}$ = 0.33 (Fig. 12). The yield isopleths was used to predict the response of relative yield-per-recruit of the fish species to changes in L_c and E. The yield contours, which predict the response of yield-per-recruit of the goby fish to changes in L_c and E, were also obtained and presented in Fig. 13.

DISCUSSION

Mekong River is one of the largest rivers in the Southeast Asia; great volumes of sediment are carried towards the coastal areas of the Mekong Delta in rainy season. Therefore, the estuarine ecosystem provides a habitat for a variety of wildlife species, as well as spawning grounds for fish (Nedeco, 1993). In the present study, the high GSI values of the goby were determined from June to November in both sexes. In addition, the HSI values also decreased during June-August and October. For gobies, Miller (1984) stated that the liver has been shown to play the leading role during the annual breeding season. The decreased in liver weight during pre-spawning probably results from the passage of materials from the liver to the gonads. Hence, the results indicated that the breeding season of the goby occurred from June to November, nearly during the rainy season (April-November) in the Mekong Delta, with two spawning peaks in July and October. This finding also agreed with the recruitment pattern which showed two recruitment peaks with an interval about 5 months.

In the present study, the GSI values of female were higher than those of male, which probably contributes towards the heavier mature females when compared to mature males. This result agrees with that of Kader *et al.* (1988) studied on reproductive biology of *Gobioides rubicundus*. The authors showed that the GSI values of females in mature stages ranged from 1.031 to 2.8879 which were also higher than those of males (ranged from 0.01 to 0.0482). They also revealed that the spawning periods of the male was extended from late January to early February and from late June to early October while those of the female extended from late January to early February and from late August to early September. Those results also indicated that *Gobioides rubicundus* spawns two times per year. Furthermore, no females with running and spent ovaries were found in the fish specimens of the present study.

In the Gangetic Delta, *P. elongatus* breeds just before the beginning of the southwest monsoon during the rainy season, i.e., from July to September (Hora, 1936). Miller (1984) and Blaber (2000) also stated that nearly all gobies are multiple-spawners; they breed for all or most of the year, often a wet season. In goby *Aphia minuta*, the breeding season is quite long and that spawning takes place at least twice during its short lifespan (Caputo *et al.*, 2003). *Acentrogobius masago* (Tomiyama) spawn on sandy mud bottoms near Kyushu from May to September; meanwhile, *Acentrogobius reichei* (Bleeker) spawns before the monsoon season, in October and November (Charles and Donn, 1966). During the breeding season, *Gobius minutus* can spawn at least three batches of eggs (Healey, 1971). The fecundity of gobiids varies widely among and within species, ranging from less than 100 eggs in *Eviota lacrimae* to over 500,000 eggs in *Awaous guamensis* (Ha and Kinzie, 1996).

The length at first maturity (L_m) is an important management parameter used to monitor whether enough juveniles in an exploited stock (Ault *et al.*, 1998). The length at first maturity (L_m) is also related closely to the asymptotic length (L_∞) and would be very interesting to assess the proportion of growth span of a species before maturation by using the dimensionless L_m/L_∞ ratio (Pauly and Munro, 1984; Beverton, 1992). Beverton (1992) stated that the L_m/L_∞ ratio range from 0.4 to 0.88 and the sex differences in the L_m/L_∞ ratios are much less pronounced and are probably insignificant. In the present study, the L_m/L_∞ ratio of both female (0.59) and male (0.63) was slightly low; however, both ratios fall within the range suggested by Beverton (1992).

According to Pauly (1987), in order to obtain true estimates of growth and other fisheries parameters, the reliability of length frequency data must be ascertained. Firstly, a minimum sample size of 1,500 fish specimens collected over a period of at least six months is adequate. Secondly, the sequentially arranged length frequency data should display distinct peaks with an apparent shift in modal length over time. In the present study, a total of 9,435 fish specimens was collected over a period of 18 consecutive months and the sequentially arranged monthly histograms displayed distinct peaks. Therefore, the length frequency data in the present study meet both prescribed criteria; and the data were analyzed using FiSAT II software for determination the fish population parameters.

The growth curves of fish are not linear, thus direct comparison of growth parameters is not biologically possible. Therefore, growth comparison must be approached from a multivariate perspective in which both L_∞ and K are taken into consideration. A comparison of growth performance of the goby *P. elongatus* with the other gobiid species was given in Table 3. The growth performance index (Φ') is a species-specific parameter, i.e., its values are usually similar within related taxa and have narrow normal distributions. Moreau *et al.* (1986) stated that the gross dissimilarity of Φ' for a number of stocks of the same species or related species is an indication of the unreliability in the accuracy of estimated growth parameters. The coefficient of variation of 9.35% together with other measures of dispersion (range = 0.6, variance = 0.05, standard deviation = 0.22 and mean = 2.3) for Φ' values in Table 3 is low. However, the Φ' in *P. elongatus* was slightly higher than that of the other species. This may be because of the long caudal fin of the goby as compared with that in the others. Cees *et al.* (1995) also reported that this species has the longest caudal fin in relation to its total length (20% TL).

The results indicate that the fish stock is not overexploited ($E = 0.49 < E_{max} = 0.65$); however, the length at first capture is lower than the length at first maturation ($L_c = 10.05 < L_m = 15.4$ cm). This shows that the fish stock is growth overexploitation. For this reason, the 15 mm mesh size codend of the fixed-bag nets should be increased. King (1995) showed that minimum mesh sizes in nets are applied in many fisheries to allow small individuals to escape and grow to a more valuable market size. A further aim may be to allow individuals to reach a size at which they can reproduce at least once before capture. Satoshi *et al.* (2002) also stated that living resources are self-reproducible. If many matured fish were caught by the fishery during and/or before spawning season, the stock of next generation would be decreased immediately.

The aims of stock assessment are to provide estimates of the size of a fisheries resource and suggest levels at which it may be exploited economically and sustainably. The outcome of stock assessment should be to provide advice to fisheries managers in the form of probable biological and economic outcomes for a range of possible management strategies (King, 1995). In the Mekong Delta, fisheries resources in the coastal mud flat areas are managed under traditional ownership by adjacent community groups and the fish stocks are regarded as a common resource. Therefore, increase in mesh size of the fishing gear and management of fishing effort may be difficult to implement and can probably only be considered if management of the fishery is devolved to the local communities. Furthermore, the difficulties are also related to a number and types of user groups. For this reason, the community-based co-management approach should be applied to the fishery for sustainable use of the fish stocks; because this approach focuses not only on resource management, but also community and economic development (Pomeroy and Viswannathan, 2003).

ACKNOWLEDGMENTS

This research was funded by the Ministry of Education and Training of Vietnam and the University Malaysia Terengganu (UTM). The authors would like to thank the technical staffs at Vinh Chau Field Station, College of Aquaculture and Fisheries, Cantho University for their field assistance.

REFERENCES

Amrendra, N.Y. and B.R. Singh, 1989. Gross structure and dimensions of the gill in an air-breathing estuarine goby, *Pseudapocryptes lanceolatus.* Japanese J. Ichthyol., 36: 252-259.

Ault, J.S., J.A. Bohnsack and G.A. Meester, 1998. A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fish. Bull., 96: 395-414.

Bagenal, T.B. and E. Braum, 1978. Eggs and Early Life History. In: Bagenal, T.B. (Ed.), Methods for Assessment of Fish Production in Freshwater. Blackwell Scientific Publications, Oxford, pp: 165-201.

Beverton, R.J.H. and S.J. Holt, 1957. On the Dynamics of Exploited Fish Populations. Chapman and Hall, London.

Beverton, R.J.H., 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. J. Fish. Biol., 41: 137-160.

Blaber, S.J.M., D.T. Brewer and J.P. Salini, 1995. Fish communities and the nursery role of the shallow inshore waters of a tropical bay in the Gulf of Carpentaria. Estuarine Coastal and Shelf Sci., 40: 177-193.

Blaber, S.J.M., 2000. Tropical Estuarine Fishes: Ecology, Exploitation and Conservation. Blackwell Science.

Bowker, D.W., 1996. The bias associated with the dispersion of length at age in the estimation of growth and mortality parameters from uni-modal length-frequency data. J. Fish Biol., 49: 743-747.

Caputo, V., M.L. Mesa, G. Candi and P.N. Cerioni, 2003. The reproductive biology of the crystal goby with a comparison to that of the transparent goby. J. Fish Biol., 62: 375-385.

Cees, S., R. Nukul, H. Michel, P. Sumalika, P. Somporn, I. Itsara, C. Witool, Y. Pun, H. Phusit and D. Samart, 1995. The five sympatric mudskippers (Teleostei: Gobioidea) of Pattani Area, Southern Thailand. The Natural History Bulletin of the Siam Society, 42: 109-129.

Charles, M.B. and E.R. Donn, 1966. Modes of reproduction in fishes, how fishes breed. American Museum of Natural History.

Chotkowski, M.A., D.G. Buth and K. Prochazka, 1999. Systematics of Intertidal Fishes. In: Intertidal Fishes: Life in two Worlds. Horn, M.H., K.L.M. Martin and M.A. Chotkowski (Eds.), Academic Press, pp: 297-331.

Clayton, D.A., 1993. Mudskippers. Oceanography Marine Biol. Ann. Rev., 31: 507-577.

Das, B.K., 1933. On the bionomics, structure and physiology of respiration in an estuarine air-breading fish, *Pseudapocryptes laceolatus* (Bloch and Schneider). Curr. Sci., 1: 389-393.

Das, B.K., 1934. The habits and structure of *Pseudapocryptes lanceolatus*, a fish in the first stages of structural adaptation to aerial respiration. Proceeding of Royal Society of London, Series B: Biological Sci., 115: 422-430.

Dinh, T.D., A.M. Ambak, H. Anuar and N.T. Phuong, 2006. Age determination and length-weight relationship of the Goby *Pseudapocrypte lanceolatus*. In: Proceedings of the KUSTEM 5th Annual Seminar on Sustainability Science and Management, 2-3 May 2006, Kuala Terengganu, Malaysia.

Etim, L., T. Brey and W. Arntz, 1996. A seminal study of the dynamics of a mudskipper (*Periophthulmus papilio*) population in the Cross River, Nigeria. Netherlands J. Aquatic. Ecol., 30: 41-48.

Etim, L., R.P. King and M.T. Udo, 2002. Breeding, growth, mortality and yield of the mudskipper *Perriophthalmus barbarus* (Linneaus 1766) (Teleostei: Gobiidae) in the Imo River estuary, Nigeria. Fish. Res., 56: 227-238.

Gayanilo, F.C., P. Sparre and D. Pauly, 1996. FiSAT: FAO-ICLARM Stock Assessment Tools. User's Manual. Rome, FAO.

Gayanilo, F.C., P. Sparre and D. Pauly, 2006. FiSAT II User's Guide. FishBase, World Wide Web electronic publication. www.fishbase.org, 10 May, 2006.

Ha, P.Y. and R.A. Kinzie, 1996. Reproductive biology of *Awaous guamensis*, an amphidromous Hawaiian goby. Environ. Biol. Fish., 45: 383-396.

Hasselblad, V., 1966. Estimation of parameters for a mixture of normal distributions. Technometrics, 8: 431-444.

Healey, M.C., 1971. Gonad development and fecundity of the sand goby, *gobius minutus* Pallas. Trans. Am. Fish. Soc., 100: 520-526.

Hora, S.L., 1936. Ecology and Bionomics of the Gobioid Fishes of the Gangetic Delta. International Congress of Zoology Lisbonne, 2: 841-864.

Ip, Y.K., S.F. Chew, A.L.L. Lim and W.P. Low, 1990. The mudskipper. In: Essays in Zoology, National University of Singapore, pp: 83-95.

Kader, M.A., A.L. Bhuiyan and A.R.M.M. Manzur-I-Khuda, 1988. The reproductive biology of *Gobioides rubicundus* (Ham. Buch.) in the Karnaphuli river estuary, Chittagong. Indian J. Fish., 35: 239-250.

Khaironizam, M.Z. and Y. Norma-Rashid, 2002. Length-weight relationship of Mudskippers (Gobiidae) in the coastal Areas of Selangor, Malaysia. Naga, 25: 20-22.

King, M., 1995. Fisheries Biology, Assessment and Management. Fishing News Books.

Matics, K.I., 2000. Gobies. Mekong fish catch and culture. Mekong Fisheries Network Newslett., 5: Supp. 8.

Miller, P.J., 1984. The Tokology of Gobioid Fishes. In: Fish Reproduction: Strategies and Tactics. Potts, W.G. and R.J. Wootton (Eds.), Academic Press, pp: 119-153.

Mohsin, A.K.M. and M.A. Ambak, 1996. Marine Fishes and Fisheries of Malaysia and Neighboring Countries (1996). Universiti Pertanian Malaysia Press.

Moreau, J., C. Bambino and D. Pauly, 1986. A Comparison of Four Indices of Overall Growth Performance Based on 100 Tilapia Populations (Fam. Cichlidae). In: The First Asian Fisheries Forum. Maclean, J.L., L.B. Dizon and L.V. Hosillo (Eds.), Asian Fisheries Society, Manila, pp: 201-206.

Murdy, E.O., 1989. A taxonomic revision and cladistic analysis of the Oxudercine Gobies (Gobiidae: Oxudercinae). Records of the Australian Museum (1989) Supplement, 11: 1-93.

Nedeco, 1993. Master plan for the Mekong Delta in Vietnam, a perspective for sustainable development of land and water resources. Netherlands Engineering Consultants.

Pauly, D., 1979. Theory and management of Tropical multi-species stocks: A review, with emphasis on the Southeast Asian demersal fisheries. ICLARM Studies and Review, No. 1.

Pauly, D. and G. Gaschutz, 1979. A simple method for fitting oscillating length growth data, with a program for pocket calculators. ICES Council Meeting Papers, pp: 26.

Pauly, D., 1980. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer, 39: 175-192.

Pauly, D. and J.L. Munro, 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2: 21.

Pauly, D. and M.L. Soriano, 1986. Some Practical Extensions to Beverton and Holt's Relative Yield-Per-Recruit Model. In: The first Asian Fisheries Forum. Maclean, J.L., L.B. Dizon and L.V. Hosillo (Eds.), Asian Fisheries Society, Manila, pp: 491-496.

Pauly, D., 1987. A Review of the System for Analysis of Length Data in Fish and Invertebrates. In: Length Based Methods in Fisheries Research. Pauly, D. and R. Morgan (Eds.), ICLARM Conference Proceeding 13, ICLARM, Manila, pp: 7-34.

Pauly, D., 1990. Length converted catch curves and the seasonal growth of fishes. Fishbyte, 8: 33-38.

Pauly, D., J. Moreau and N. Abad, 1995. Comparison of age-structured and length converted catch curves of brown trout *Salmo trutta* in two French rivers. Fish. Res., 22: 197-204.

Pomeroy, R.S. and K.K. Viswannathan, 2003. Experiences with Fisheries Co-Management in Southeast Asia and Bangladesh. In: The Fisheries Co-Management Experience. Douglas, C.W., R.N. Jesper and D. Poul, (Eds.), Accomplishments, Challenges and Prospects. Kluwer Academic Publishers, pp: 99-117.

Powell, D.C., 1979. Estimation of mortality and growth parameters from the length frequency in catch. J. Cons. Int. Explor. Mer., 175: 167-169.

Rainboth, W.J., 1996. Fishes of the Cambodian Mekong. FAO Species Identification Field Guide for Fishery Purposes. FAO, Rome.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can.

Satoshi, I., A. Syed and M.I. Mansor, 2002. Aging study for tropical fish using otolith microstructure. Fisheries Research Technical Report Series 1, SEAFDEC.

Sparre, P., E. Ursin and S.C. Venema, 1989. Introduction to tropical fish stock assessment. Part 1-Manual, FAO.

Taylor, C.C., 1958. Cod growth and temperature. J. Cons. Int. Explor. Mer., 23: 366-370.

Vesey, G. and T.E. Langford, 1985. The biology of the black goby, *Gobius niger* L. in an English South-coast bay. J. Fish. Biol., 27: 417-429.

Weber, M. and L.F. De Beaufort, 1953. The fishes of the Indo-Australian archipelago. X. Gobioidea. A. J. Reprints Agency, New Delhi.

Wetherall, J.A., 1986. A new method for estimating growth and mortality parameters from length frequency data. Fishbyte, 4: 12-14.

Zar, J.H., 1999. Biostatistical Analysis. Prentice-Hall, London.