Some Aspects of the Population Biology of the Green Tiger Prawn *Penaeus semisulcatus* (De Haan, 1844) from Pilar and Capiz Bays, Northern Panay, West Central Philippines

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ABSTRACT

This study is a first report on the population biology of the green tiger prawn *Penaeus semisulcatus* (de Haan) from northern Panay, west central Philippines. The study was conducted for eight months (May to December 2002) whereby total lengths of both male and female *P. semisulcatus* of various sizes were measured monthly from the catches of municipal trawlers operating at Pilar and Capiz Bays. Based on the Bhattacharya method, a mean growth rate of 0.78 ±0.28 and 1.45 ±0.39 mm/day were estimated for males and females, respectively. Using the ELEFAN I method, growth parameters derived for males were L_∞ = 263 mm, k = 0.7/yr and a growth index (Ø) of 4.69. On the other hand, growth parameters derived for females were L_∞ = 271 mm, k = 1.6/yr and a growth index (Ø) of 5.07.

Based on length-converted catch curve analysis, the total mortality (Z) of the male population is estimated to be 3.61/yr while that of the females is 5.65/yr. Male prawns showed a higher exploitation rate (0.53) compared to that of the females (0.35) indicating the susceptibility of males to fishing. This study also revealed that trawlers in Pilar and Capiz Bays are already getting small sizes of prawns, without allowing them to reach sexual maturity. Hence, there is a need to increase the present mesh size (2.5 cm) of the cod end of trawls in order to avoid growth overfishing, which may occur with continued increase in fishing effort. Furthermore, the recruitment pattern showed two pulses of unequal strengths and time, dividing the year into a 7-5 month pattern. The said pattern, especially for females, may have resulted from a major and minor spawning peak of the said species during the months of June-September and January.

Keywords: Penaeus semisulcatus, growth, recruitment pattern, mortality, Pilar and Capiz Bays

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INTRODUCTION

The green tiger prawn, *Penaeus semisulcatus* de Haan (1844), locally known in Panay as "bulik", is known to inhabit sandy or muddy-sand bottoms and is caught by trawls in depths down to 130 meters (Dore and Frimodt, 1987; FAO, 1998). In Pilar and Capiz Bays, northern Panay the trawl fishery exists mainly for the invertebrates (del Norte-Campos et al. 2003). *P. semisulcatus* ranks high among commercially important invertebrates in Panay and demands a high price in the local market making it one of the target species of trawl operators (del Norte-Campos et al. 2000).

In the Philippines, Agasen and del Mundo (1988) studied the growth, mortality and exploitation rates of the white prawn *Penaeus indicus* in Manila Bay. In spite of their significance, there is no other account on the quantitative assessment of shrimp resources here in the country. As for *P. semisulcatus*, studies that have been conducted in the Philippines focused on the food and feeding habits (Tiews et al. 1976; del Norte-Campos et al. 2004) and the reproductive cycle (Villarta and del Norte-Campos, 2004) of the species. Outside the country, however, several studies on some aspects of the population dynamics of the species have been undertaken (Thomas 1975, Garcia and Le Reste 1981, Mohamed et al. 1981, Kirkwood and Somers 1984, Siddeek 1991, Xu et al. 1995, Ye and Mohammed 1999, and Mehanna 2000).

Here in the country, studies on population dynamics have focused mainly on fish while the arguably equally important marine invertebrates have received less attention. Penaeid shrimps, for example, are less studied although they are one of the most valuable fishery resources. These commercially exploited species are not only consumed locally but exported outside the country as well. In BFAR statistics (2003), shrimp/prawn ranked 2nd among major fishery exports in terms of value. This strong demand may result to a further increase in the fishing effort in the trawl fishery which may affect the total production of shrimp in the country. In this line, it is important to study not only their reproductive activity but also the effect of the rate of exploitation to the dynamics of its population. Hence, there is a need for studies on the biology and stock assessment of the species to ensure that these resources continue to be sustainable.

The present paper is the first account of some aspects of the population biology of *P. semisulcatus* from Pilar and Capiz Bays, northern Panay, as an endeavor to contribute information to its general biology. This study aims to estimate some basic parameters needed for establishing a management plan to ensure that this resource continue to be viable.

MATERIALS AND METHODS

Study area and survey

The sampling was conducted for eight months (May to December 2002) in Libas port, Brgy. Libas, Roxas City. Total length of shrimps, measured from the tip of rostrum to the tip of the telson, was determined to the nearest millimeter using a ruler. Measurements were done monthly for both male and female *P. semisulcatus* of various sizes taken from the catches of municipal trawlers, which operate in Pilar and Capiz Bays, northern Panay, located between 122°40'-55' E and 11°36'-43' N (Figure 1), and dock at Libas port. The depth of trawling operation for these vessels is between 5-25 fathoms (9-46 m) with the net used for fishing having a mesh size at the cod end of 2.5 cm.

Laboratory and data analyses

Monthly length measurements (TL) were grouped into 10 mm size classes (50-50.99, 60-69.99, 70-79.99, etc. mm) and analyzed using the Bhattacharya (1967) method, incorporated in the FiSAT software (FiSAT, 1997).

To compute growth rates (mm/day) by cohort, increments between the modal lengths (mm) derived using the Bhattacharya method, were divided with their respective time increments (days). Mean growth rates for each cohort were averaged to estimate the annual mean growth rate for all cohorts.

The growth parameters L_∞ and k were derived using the ELEFAN I. The growth index Ø was computed according to the equation of Pauly and Munro (1984) as follows:

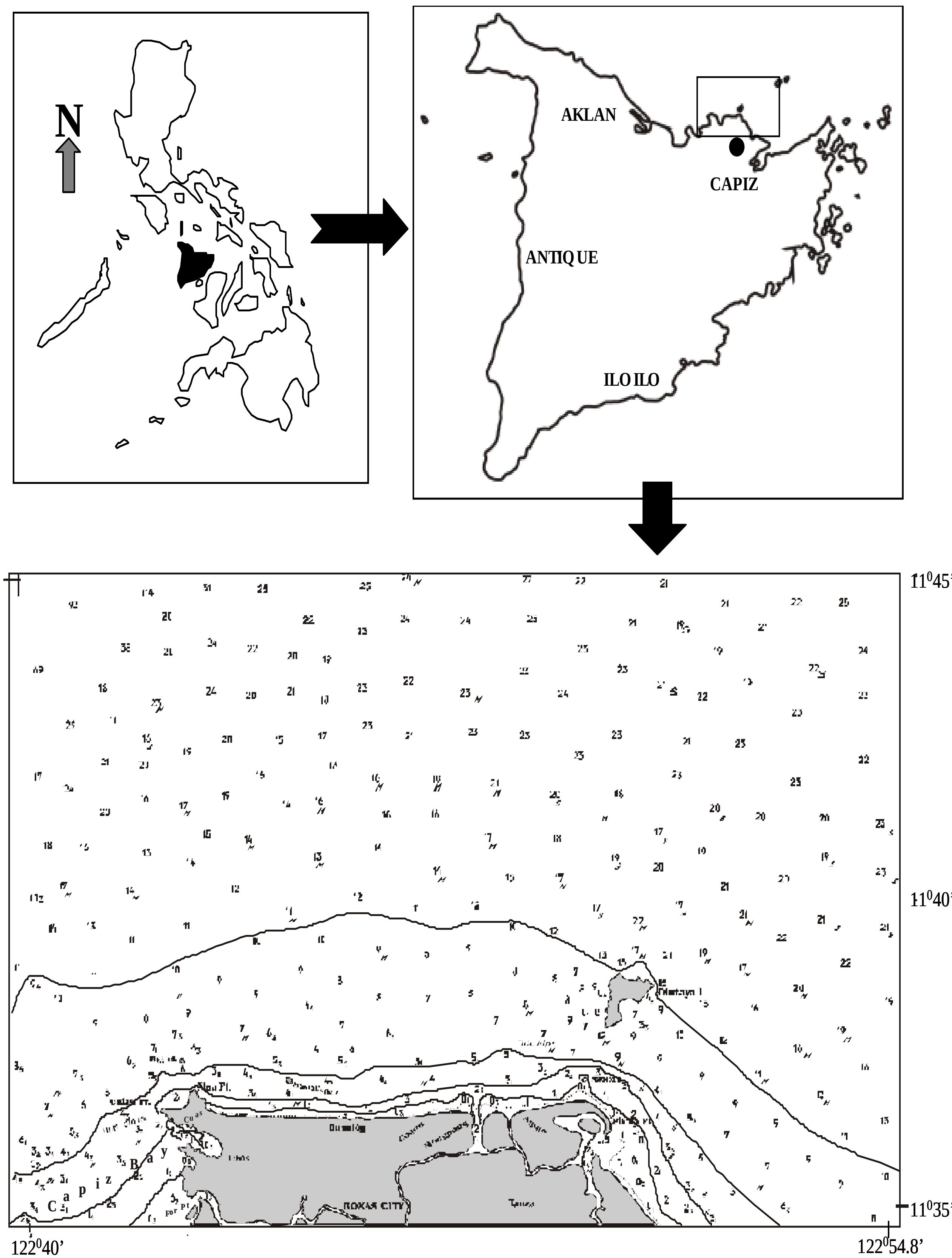

Figure 1. Map showing the study area, Pilar and Capiz Bays, northern Panay. Numbers indicate depths in fathoms.

$$Ø' = \log k + 2 \log L_\infty$$

where k is the growth constant per year and L∞ is the asymptotic length (TL). The values derived for growth were then compared with those of other studies on penaeid shrimps.

The mean recruitment patterns, as well as the instantaneous total mortality (Z per year) were determined using the ELEFAN II program. In this method, the recruitment pulses were reconstructed from the length-frequency data to determine the number of pulses per year and the relative strength of each pulse. ELEFAN II outputs the points in percent of the recruitment in one year; from this a recruitment graph is made. The peaks show the number of recruitment seasons.

Total mortality Z was derived using the length-converted catch curve analysis. This was estimated from the slope of the catch curve derived from the length frequency data. The catch curve is the graph of the natural logarithm of the number of prawns of a given age against their age.

Natural mortality (M) was estimated by computing an average M/k ratio from shrimp literature (Agasen and del Mundo 1988, Sumiono 1988, Mehanna 2000 and Campos and Berkeley 2003) then multiplying this value by the k derived from the length frequency data for the species. Fishing mortality (F) was then computed based on the definition: F = Z - M. Exploitation rate, i.e. the rate of fishing mortality to total mortality was computed from: E = F/Z. The derived estimates were then compared with other studies to allow further assessment.

RESULTS AND DISCUSSION

Growth

The total number of samples ranged from 90 to 209 for females and 194 to 220 per month for males. Size frequency data, for both female and male, collected from May to December 2002 are plotted in Figures 2 and 3, respectively. For females, the smallest individuals (75 mm TL) were observed in the months of May, June, August and September, while the largest

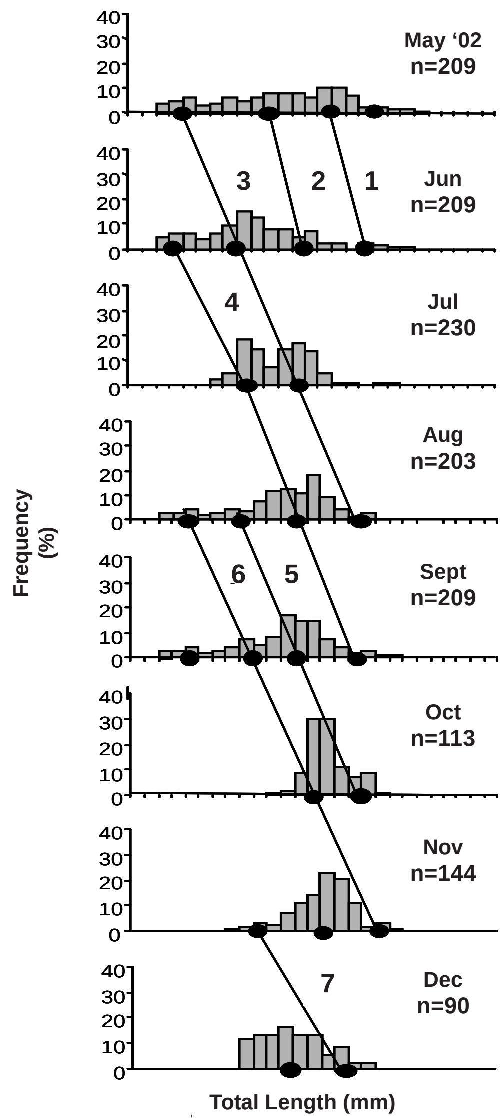

Figure 2. Length frequency distribution of the green tiger prawn *Penaeus semisulcatus* (female), May-December 2002, collected from Pilar and Capiz Bays, northern Panay.

sizes (> 215 mm) were found in all months (Figure 2). Most individuals, however, fell within the range of 145-195 mm TL. The smallest male individual (65 mm TL) was found in the month of June while large sizes (> 215 mm) were found in the month of May (Figure 3). Most male prawns fell within the range of 115-155 mm TL. These results reveal that females are generally larger than the males.

Villarta and del Norte-Campos (2003) reported that the minimum sizes of sexual maturity for male and female green tiger prawn from Pilar and Capiz Bays are 123 and 145 mm TL, respectively. Furthermore, partially spawned gonads were already observed at smaller sizes, based on histology, (i.e. 104 mm for males and 143 mm for females) indicating that this species can be mature at sizes smaller than what were recorded. Using this as basis, it was computed from the length-frequency data that 1.25% of male and 24.4% of female samples were not yet sexually mature. This indicates that trawlers in Pilar- and Capiz Bays are already getting smaller sizes of prawns, without allowing them to reach sexual maturity. A further increase in fishing effort may result in growth overfishing, which takes place when resources are fished at an average size that is smaller than the size that would produce the maximum yield per recruit. To avoid this, it is important that *P. semisulcatus* be caught at sizes larger than the recorded size at sexual maturity. Hence, there is a need for an increase in the currently used mesh size (2.5 cm) of the cod end of trawls operating in the area.

Based on the Bhattacharya method, a total of 7 cohorts were derived for females (Figure 2). Daily growth rates ranged from 0.51 to 1.98 mm/day, with a mean annual growth rate of 1.45 ±0.39 mm/day (n=14) (Table 1A). On the other hand, 4 cohorts were derived for male prawns (Figure 3), with daily growth rates ranging from 0.49 to 1.03 mm/day and a computed mean annual growth rate of 0.78 ± 0.28 mm/day (Table 1B). The relatively higher growth rate of the female green tiger prawn is in agreement with the larger sizes they attain as also pointed out by Thomas (1975). This result also agrees with Mehanna (2000) who also reported a higher growth rate of female *P. semisulcatus* from the Gulf of Suez, Egypt.

The Von Bertalanffy Growth Function parameter estimates derived for females using ELEFAN I were L_∞ = 271 mm and k = 1.6 per year. The growth index (Ø) computed from these parameters was 5.07. VBGF parameters for males were L_∞ = 263 mm and k = 0.7 per year and a growth index (Ø) of 4.69. It has been observed that the growth constant (k) was higher in females confirming the high growth rate drawn from the Bhattacharya analysis. However, this estimated k for males differed markedly from other estimates reported in other studies. This may have resulted from the high value for male asymptotic length (L_∞) derived in this study compared to those obtained from other areas. Nevertheless, the growth performance indices (Ø) for both male and female obtained from this study compare well with the study of Mehanna (2000) for the same species. To further allow comparisons with the derived estimates, growth parameters for other penaeid species from other areas are shown in Table 2.

The growth parameters derived using the Bhattacharya analysis and the von Bertalanffy growth formula were found to agree quite well. The estimated values from

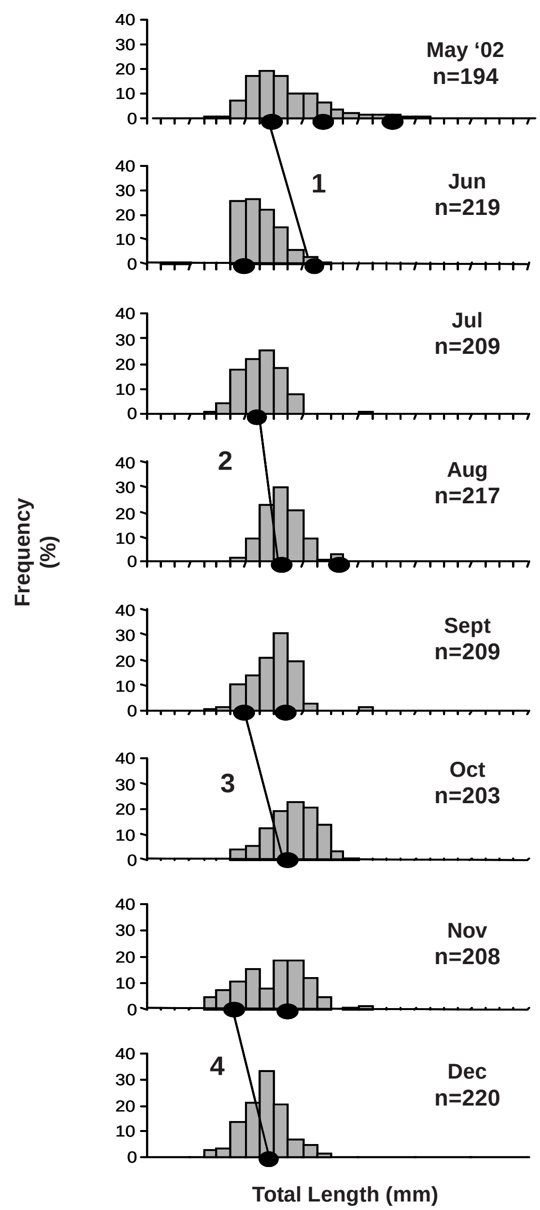

Figure 3. Length frequency distribution of the green tiger prawn *Penaeus semisulcatus* (male), May-December 2002, collected from Pilar and Capiz Bays, northern Panay.

A. Cohort No.	L_{t+1} (mm)	L_t (mm)	$L_{t+1} - L_t$ (mm)	t+1 - t (days)	Growth rate (mm/day)
I	219.23	203.84	15.39	30	0.51
II	183.49	154.52	28.97	30	0.97
III	222.87	175.10	47.77	30	1.59
	175.10	138.28	36.83	30	1.23
	138.28	88.08	50.20	30	1.67
IV	220.00	171.70	48.30	30	1.61
	171.70	141.43	30.26	30	1.01
	141.43	88.15	53.28	30	1.78
V	221.89	177.65	44.24	30	1.47
	177.65	128.16	49.50	30	1.65
VI	236.96	190.24	46.72	30	1.56
	190.24	136.09	54.15	30	1.81
	136.09	93.33	42.76	30	1.43
VII	205.95	146.42	59.53	30	1.98
Mean	**188.63**	**145.21**	**43.42**	**30.00**	**1.45**
Sd	**33.94**	**37.05**	**11.83**	**0.0**	**0.39**
n	**14**	**14**	**14**	**14**	**14**

B. Cohort No.	L_2 (mm)	L_1 (mm)	$L_{t+1} - L_t$ (mm)	t+1 - t (days)	Growth rate (mm/day)
I	168.05	137.87	30.18	30	1.01
II	144.28	129.55	14.74	30	0.49
III	152.21	121.30	30.91	30	1.03
IV	136.50	118.97	17.53	30	0.58
Mean	**150.26**	**126.92**	**23.34**	**30.00**	**0.78**
Sd	**13.48**	**8.59**	**8.40**	**0.0**	**0.28**
n	**4**	**4**	**4**	**4**	**4**

Table 1. Growth rates of the derived cohorts of female (A) and male (B) *Penaeus semisulcatus* sampled from May-December 2002 in Pilar-Capiz Bays, northern Panay.

both methods gave similar trends in the growth rates of both sexes of green tiger prawn. Vibhasiri (1988) also stressed the aptness of the use of the said methods for *Metapenaeus affinis* in the Gulf of Thailand.

Since molts are separated by intermolt periods in the growth pattern of penaeid shrimps (Garcia, 1988), the modal progression analysis of carapace length or body length is usually used for age estimation. Also, it has been well reported that both male and female penaeids attain their highest growth rate during the first three months of life, after which, the increment in length gradually decreases with further increase in age. Based on the data, the oldest calculated ages for *P. semisulcatus* in the sample are 2.4 yrs for females and 3.8 yrs for males. These values may be assumed to be the longevity (t_{max}) periods for both the male and female. For the females, this result compare well with that of Mehanna (2003) for the same species in the Gulf of Suez. However, longevity for males in this study was found to be double that of the male population in Gulf of Suez. This may be attributed to the low k value obtained for males. It may be that the growth formula used in this study was not appropriate for the male samples since it may have been biased towards smaller male individuals which occurred in higher frequencies, thus resulting in the low k value.

Recruitment pattern

The derived recruitment pattern for both female and male *P. semisulcatus* using ELEFAN II consists of two peaks of unequal strengths and durations, dividing the year into a 7-5 month pattern (Figure 4). Major peak

Species	CL_∞ (mm) ♀	♂	TL_∞ (mm) ♀	♂	k (per yr) ♀	♂	Ø' ♀	♂	Area and year	Literature
Penaeus semisulcatus			271.0	263.0	1.60	0.70	5.07	4.69	Pilar-Capiz Bays, Philippines, 2002	this study
			268.0	224.0	1.56	1.77	5.05	4.95	Gulf of Suez, Egypt, 1997/1998	Mehanna (2000)
	48.00	39.50			1.69	1.33	3.59	3.32	Southern Kuwaiti waters, 1982-1983	Siddeek and Abdul-Ghaffar, 1991, in Siddeek (1991)
P. orientalis			201.3	163.5					Po Hai Sea, China	Jingyao, 1981 in Ye (1984)
P. indicus	41.50	40.50	210.0	205.0	1.00	1.20	2.64	2.70	Manila Bay, 1982	Agasen and del Mundo (1988)
	44.70	43.40	226.0	220.0	1.00	1.20	2.71	2.75	Punnaikkayal, India, 1978	Agasen and del Mundo (1988)
	42.34	40.70	214.0	206.0		1.10		2.71	Manappad, India, 1978	Agasen and del Mundo (1988)
P. merguiensis	53.10	43.80			1.15	1.60	3.51	3.49	South coast of Java 1977-1979	Sumiono (1988)
	53.20	42.40			0.90	1.50	3.41	3.43	South coast of Java 1982-1984	Sumiono (1988)
P. duorarum	43.40	33.20	187	146.1	1.72	1.61	3.70	3.46	Biscayne Bay, Florida 1986	Campos and Berkeley (2003)

Table 2. Growth parameters of some penaeid species in various areas of study (Ø' + log k + 2 log $L\infty$).

for females accounted for 92.04% and the remaining 7.96% for the minor peak. On the other hand, the major recruitment peak for males accounted for 90.86% and 9.14% for the minor peak. The length-frequency data for female individuals show highest recruitment during the months of May, June, August and September, whereby, small individuals occur in significant number. Based on the reproductive data of females (Villarta and del Norte-Campos, 2003), spawning activity peaks during the southwest monsoon (June to September), which could be taken to correspond to this major recruitment pulse. The minor pulse, on the other hand, occurred in January corresponding to individuals with developing gametes. Crocos and van der Velde (1995) also described a bimodal spawning pattern for penaeids. However, despite the 2 peaks recruitment occurs year-round since mature females can be found at any time of the year (Villarta and del Norte-Campos, 2003). The case is also true for males wherein they are reported to have a gametogenic activity the entire year; hence, recruitment also occurs the entire year.

Mortality

Based on length-converted catch curve analysis the total mortality (Z) for both female and male *P. semisulcatus* is equivalent to 5.65 and 3.61, respectively.

As estimated from M/k values averaged from literature (Table 3) and subsequently multiplied with the estimated k for male and female prawns in this study, the values for natural mortality (M) are 3.65 for females and 1.70 for males. These values when subtracted from the Z values give estimate fishing mortality (F) values of 2.00 and 1.91 for females and males, respectively. Exploitation rates for both sexes were then computed to be 0.35 for females and 0.53 for males.

As shown in Table 3, results from other studies on penaeid prawns show higher mortality values in males than in females contrary to what was obtained from this study. Nonetheless, a similar trend in exploitation rate (E) was observed wherein males obtained higher values compared to those of the females. As suggested by Gulland (1971), if natural mortality is less than or equal to fishing mortality (i.e., if $E > 0.5$) then the stock is said to be overexploited. In this study, it was observed that the exploitation rate (E) for male green tiger prawn was greater than 0.5, indicating that the male stock is exploited. This may be attributed to the differences in behavior between sexes. As in the case of *Penaeus*

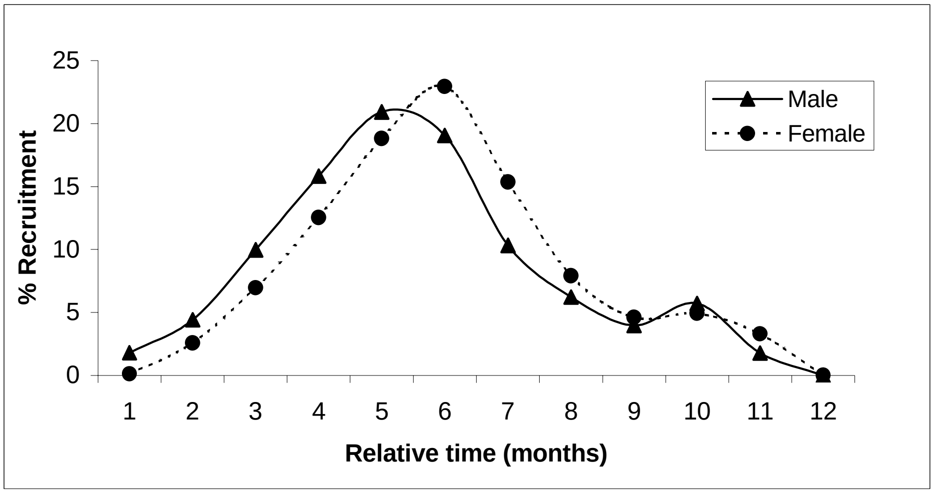

Figure 4. Recruitment pattern of male and female P. semisulcatus from Pilar and Capiz Bays, northern

merguiensis from the south coast of Java (Sumiono, 1988), high mortality and exploitation rates observed in male *P. semisulcatus* from Pilar and Capiz Bays could be a result of their vulnerability to the fishery than females of the same size. It may be that females have different migration patterns and move out of the fishing grounds for spawning. *P. semisulcatus* which has a Type 3 life cycle spawns offshore and the larvae develop there, while the juveniles develop in inshore waters in seagrass or algal beds (Haywood et al., 1995). This movement of adults from shallow coastal waters to offshore to mate and spawn is observed generally in penaeids (Baldock, 1999; FAO, 1998) although it is also reported that penaeid prawns, in some areas, undertake a short shoreward migration before spawning (Dall et al. 1990; Garcia, 1988; Ye, 1984). In one study, George and Rao (1967) attributed variation in sex ratios of different penaeid prawns to the movement of females out of the fishing grounds to deeper waters for spawning. Rao (1989) also suggested a sex-wise

Species	Z (per yr)		M (per yr)		k (per yr)		M/k		F		F/Z		Area and year	Literature
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂		
Penaeus	5.65	3.61	3.65	1.70	1.60	0.70			2.00	1.91	0.35	0.53	Pilar-Capiz Bays, 2002	this study
semi-sulcatus	6.77	8.18	2.20	2.52	1.56	1.77	1.41	1.42	4.57	5.66	0.68	0.69	Gulf of Suez, Egypt, 1997/1998	Mehanna (2000)
P. indicus	4.34	4.90	1.94	2.20	1.00	1.20	1.94	1.83	2.40	2.70	0.55	0.55	Manila Bay, 1982	Agasen and del Mundo (1988)
	3.34	5.37	1.83	2.08	1.00	1.20	1.83	1.73	1.51	3.29	0.45	0.61	Punnaikkayal, India, 1978	Agasen and del Mundo (1988)
		2.94		1.98		1.10		1.80		0.96		0.33	Manappad, India, 1978	Agasen and del Mundo (1988)
P. mer-merguiensis	4.50	11.10	3.40	6.50	1.15	1.60	2.96	4.06	1.10	4.60	0.24	0.41	South coast of Java	Sumiono (1988) 1977-1979
	4.90	9.50	3.40	6.50	0.90	1.50	3.78	4.33	1.50	3.00	0.31	0.32	South coast of Java 1982-1984	Sumiono (1988)
P. duo-rarum	3.84	3.88	3.00	2.99	1.72	1.61	1.75	1.86	0.84	0.89	0.22	0.23	Biscayne Bay, Florida, 1986	Campos and Berkeley (2003)
Mean	4.76	6.18	2.77	3.31	1.28	1.33	**2.28**	**2.43**	1.99	2.88	0.40	0.46		

Table 3. Comparison of mortality indices in different species of prawns from various areas of study.

segregation of the brown prawn *Metapenaeus monoceros* in the fishing grounds of Kakinada Coast, India, as an explanation to significant differences in sex ratio, while Ramamurthy et al. (1978) ascribed it to breeding movements. Furthermore, this difference in sex ratio may be due to differential growth and mortality between the sexes as pointed out by Devi (1987) for the Indian white prawn *P. indicus* from Kakinada, east coast of India. Hence, gear efficiency of the trawl may be dependent on the behavior differences between sexes since trawlers in Pilar and Capiz Bays operate only within 5-25 fathoms albeit year-round.

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REFERENCES

Agasen, E.V. and C.M. del Mundo. 1998. Growth, mortality and exploitation rates of *Penaeus indicus* in Manila Bay, Philippines and Southern India. In Venema, S.C., J. Möller-Christensen and D. Pauly (eds.). FAO Fisheries Report 389. Rome.

Baldock, C. 1999. Environmental impact of the establishment of exotic prawn pathogens in Australia. Australian Quarantine and Inspection Service (AQIS) Consultancy Report. 115 p.

Bhattacharya, C.G. 1967. A simple method of resolution of a distribution into Gaussian components. Biometrics. 23: 115-135.

Campos, W.L. and S.A Berkeley. 2003. Impact of the commercial fishery on the population of bait shrimp *(Penaeus spp.)* in Biscayne Bay 1986. NOAA/University of Miami Joint Publication. A Final Report to Metropolitan Dade County, Department of Environmental Resources Management. 34 p.

Crocos, P.J. and T.D. van der Velde. 1995. Seasonal, spatial and interannual variability in the reproductive dynamics of the grooved tiger prawn, *Penaeus semisulcatus* de Haan, in Albatross Bay, Gulf of Carpentaria, Australia: the concept of effective spawning. Mar. Biol. 122: 557-570.

Dall, W. B.J. Hill, P.C. Rothlisberg, and D.J. Staples. 1990. The biology of the penaeidae. Adv. Mar. Biol. 27: 1-489.

del Norte-Campos, A.G.C., R.A. Beldia, K.A. Villarta, and M.A.O. Tad-y. 2000. A market survey of commercially-important invertebrates around Panay Island and use of the data to prioritize research. UPV J. Nat. Sci. 5(2): 11-25.

del Norte-Campos, A.G., K.A. Villarta and J.B. Panes. 2003. Invertebrate trawl fishery of Pilar and Capiz Bays, northern Panay, west central Philippines. UPV J. Nat. Sci. 8(1 & 2): 115-128.

del Norte-Campos, A.G.C., I. Alabia, and F. Nabuab. 2004. Natural diet composition of the red crab *Charybdis feriatus* and *Penaeus semisulcatus* in Pilar and Capiz Bays, northern Panay. UPV J. Nat. Sci. 9(1): 70-78.

Devi, S.L. 1987. Biology of the Indian white prawn, *Penaeus indicus* H.M. Edwards from Kakinada, east coast of India. Indian J. Mar. Sci. Vol. 16: 246-248.

Dore, I. and C. Frimodt. 1987. *An illustrated guide to shrimp of the world.* Osprey Books, P.O. Box 965, Huntington, NY 11743, U.S.A. and Scandinavian Fishing Year Book, Baekgaardsvej 1 2640 - Hedehusene, Denmark: 229 p.

FAO, 1998. FAO Species Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Pacific. Vol. 2 (Cephalopods, Crustaceans, Holothurians & Sharks): 925. In Carpenter, K.E. and V.H. Niem (eds.). Food and Agriculture Organization, Rome.

FAO-ICLARM stock assessment tools (FiSAT). 1997. Reference manual. FAO Computerized Information Series (Fisheries). In Gayanilo, F.C., Jr. and D. Pauly (eds.). No. 8. Rome, Food and Agriculture Organization. 262p.

Garcia, S. 1988. Tropical penaeid prawns. In J.A. Gulland (ed.), Fish population dynamics, 2nd ed. John Wiley, Chichester, p. 219-249.

Garcia, S.M. and L. Le Reste. 1981. Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. FAO Fisheries Technical Paper No. 203-215.

George, M.J. and P. Vedavysa Rao. 1967. Distribution of sex ratios of penaeid prawns in the trawl fishery off Cochin. Proc. Symp. Crustacea, Mar. Biol. Ass. India, Part II: 698-700.

Gulland, J.A., ed. 1971. The fish resources of the ocean. FAO/Fishing News Book, Ltd., Surrey, England.

Haywood, M.D.E., D.J. Vance and N.R. Loneragan. 1995. Seagrass and algal beds as nursery habitats for tiger prawns *(Penaeus semisulcatus* and *P. esculentus)* in a tropical Australian estuary. Mar. Biol. 122: 213-223.

http://www.bfar.da.gov.ph/styles/Publications/external_trade(03).htm

Kirkwood, G.P. and I.F. Somers. 1984. Growth of two species of tiger prawn, *Penaeus esculentus* and *P. semisulcatus*, in the western Gulf of Carpentaria. Aust. J. Mar. Freshw. Res. 25: 703-12.

Mehanna, S.F. 2000. Population dynamics of *Penaeus semisulcatus* in the Gulf of Suez, Egypt. Asian Fish. Sci. 13: 127-137.

Mohamed, K.H., M. El-Musa and A.R. Abdul-Ghaffar. 1981. Observations on the biology of an exploited species of shrimp, *Penaeus semisulcatus* De Haan, in Kuwait. Kuwait Bull. Mar. Sci. 2:33-52.

Pauly, D. and J.L. Munro. 1984. Once more on the comparison of growth in fish and invertebrates. Fishbyte, 2(1): 21.

Ramamurthy, S., G.G. Annigeri and N.S. Kurup. 1978. Resources assessment of the penaeid prawn *Metapenaeus dobsoni* (Miers) along Mangalore coast. Indian J. Fish. 25(1 & 2): 52-56.

Rao, G.S. 1989. Studies on the reproductive biology of the brown prawn *Metapenaeus monoceros* (Fabricus, 1798) along the Kakinada coast. Indian J. Fish. 36(2): 107 - 123.

Siddeek, M.S.M. 1991. Estimation of natural mortality of Kuwait's grooved tiger prawn *Penaeus semisulcatus* (de Haan) using tag-recapture and commercial fisheries data. Fish. Res. 11: 109-125.

Sumiono, B. 1988. Estimation of growth and mortality in banana prawn *(Penaeus merguiensis)* from the south coast of Java, Indonesia. In Venema, S.C., J. Möller-Christensen and D. Pauly (eds.). FAO Fisheries Report 389. Rome.

Thomas, M.M. 1975. Age and growth, length-weight relationship and relative condition factor of *Penaeus semisulcatus* de Haan. Ind. J. Fish. 22: 133 -142.

Tiews, K., S.A. Bravo and I.A. Ronquillo. 1976. On the food and feeding habits of some Philippine shrimps in Manila Bay and San Miguel Bay. Phil. J. Fish. 14(2): 204-212.

Vibhasiri, A. (1988). An assessment of Jinga shrimp, *Metapenaeus aiffinis* (Penaeidae), in Ban Don Bay, Gulf of Thailand. In Venema, S.C., J. Möller-Christensen and D. Pauly (eds.). FAO Fisheries Report 389. Rome.

Villarta, K.A. and A.G.C. del Norte-Campos. 2004. Reproductive cycle of the green tiger prawn *Penaeus semisulcatus* (de Haan, 1844) from Pilar-Capiz Bays, northern Panay. UPV J. Nat. Sci. 9(1): 147-156.

Xu, X., J.M. Bishop, H.M.A. Mohammed, and A.H. Alsaffar. Estimation of the natural mortality rate of green tiger prawns *Penaeus semisulcatus* (de Haan, 1844) in Kuwait waters using relative abundance data. J. Shellfish Res. 14(1): 179-184.

Ye, C.C. 1984. The prawn *(Penaeus orientalis* Kishinouye) in Pohai Sea and their fishery. In J.A. Gulland and B.J. Rothschild (eds.), Penaeid shrimps: their biology and management. Fishing New Books, Farnham, England, p. 49-59.

Ye, Y. and H.M.A. Mohammed. 1999. An analysis in variation in catchability of green tiger prawn, *Penaeus semisulcatus,* in waters off Kuwait. Fish. Bull. 97: 702 - 712.