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Population Dynamics of Shrimps in Littoral Marine Waters of the Mekong Delta, South of Viet Nam

[1]T.D. Dinh, [2]J. Moreau, [1]M.V. Van, [1]N.T. Phuong and [1]V.T. Toan
[1]Department of Fisheries Management and Economics, College of Aquaculture and Fisheries, Cantho University 3/2 Street, Cantho City, Viet Nam
[2]Laboratoire d'Ecologie Fonctionnelle, UMR 5245, ENSAT, BP 32607, Auzeville Tolosane, 31326 Castanet Tolosan, France

Abstract: The population dynamics of eight commercial species of shrimp (*Haliporoides sibogae*, *Harpiosquilla harpax*, *Metapenaeus affinis*, *Metapenaeus brevicornis*, *Metapenaeus tenuipes*, *Parapenaeopsis cultrirostris*, *Parapenaeopsis gracillima* and *Parapenaeus maxilipedo*) distributed in littoral marine zone of the Mekong Delta were investigated. Length-based stock assessment using FiSAT II software package was used to assess the growth and mortality parameters: Asymptotic size (L_8), growth coefficient (K), total (Z) and natural (M) mortality, exploitation rate (E), recruitment pattern, current probability of capture and selectivity of fishing gears. Yield-per-recruit analyses were carried out showing different levels of the exploitation. Results showed that the maximum sustainable yield would be reached for an exploitation rate higher than the current one for each population. However, the size of first capture should be increased for every population. The findings indicated that the current exploitations of shrimp populations distributed in littoral marine zone of the Mekong Delta are under exploitation level for maximum sustainable yield; however, all the shrimp populations are subject to growth over-exploitation.

Key words: Shrimp, mekong delta, population parameters, length-based, exploitation and management

INTRODUCTION

The population abundance of aquatic resources varies according to births (reproduction and recruitment) and deaths (natural and fishing mortality), whereas the total biomass also depends in growth (Metcalfe *el al*., 2008). Studies on the population dynamics, the mathematical models are useful for predicting future yields and stock biomass at different levels of fishing mortalities and they also extensively used for defining management strategies. The knowledge about growth and mortality of the populations is an essential pre-requisite for the derivation of these models. Information on growth rate and maximum size, the probability of capture relative to size for a fishing gear and mortality resulting from natural causes and fishing, can all be estimated from length frequency data which have the advantage of being relatively cheap, straightforward and quick to collect from landing sites and markets (Pilling *et al*., 2008).

In tropical and sub-tropical waters, despite the difficulty in determining growth of shrimp, the dynamic pool models have, unfortunately, been under-utilized for defining management strategies in fisheries. However, with the development of length-based stock assessment methodologies, it is possible to investigate population dynamics of aquatic resources in tropical waters (Pauly and Morgan, 1987). They become a major technique for determination the parameters of shrimp population and management because they allow an evaluation of yield to changes in fishing mortality and length at capture, two output control measures in managing a fishery (Lalitha, 1987; Garcia, 1988; Guerao *et al*., 1994; Enin *et al*., 1996; Oh *et al*., 1999; Nassir *et al*., 2007; Botter-Carvalho *et al*., 2007).

In Vietnam, marine fisheries are considered the small scale and are concentrated in coastal near-shore waters. This has resulted in heavy pressure on near-shore fisheries resources (Pomeroy *et al*., 2009). Coastal fisheries are an important component of the fishery sector. The fisheries resources consist dominantly of species with relatively high growth, natural mortality and recruitment and exhibit maximum abundance in shallow depths. Fishermen use a multiplicity of gears, with heavy concentration in near shore areas where abundance, catch rates and shrimp availability are highest. More than 100 species of shrimp are found in Vietnam and over haft

Corresponding Author: Tran Dac Dinh, Department of Fisheries Management and Economics, College of Aquaculture and Fisheries, Cantho University 3/2 Street, Cantho City, Viet Nam

of these are commercial species. Shrimps are concentrated in shallow waters, especially in the estuarine areas of the Mekong Delta. Steen and Thi (2008) reported that despite a reduction in catch rates, shrimp is still the principal resource for the trawl fleets in South Vietnam. In the Mekong Delta, shrimp fisheries are dominated by several commercially important species such as *Haliporoides sibogae*, *Harpiosquilla harpax*, *Metapenaeus affinis*, *Metapenaeus brevicornis*, *Metapenaeus tenuipes*, *Parapenaeopsis cultrirostris*, *Parapenaeopsis gracillima* and *Parapenaeopsis maxillipedo*. Despite their commercial importance, they have been poorly investigated, especially the dynamics of shrimp populations distributed in coastal areas. Therefore, the present study was carried out to investigate several demographical characteristics of these species with a view to identifying management schemes needed for the management of this valuable resource in the Mekong Delta.

MATERIALS AND METHODS

Sampling: The sampling was monthly carried out from September 2006 to August 2007 in the coastal mud flat area of Soc Trang and Bac Lieu Province, the Mekong Delta, South of Vietnam (Fig. 1). There are six sampling sites in the study area with depths about 10 m. Fresh samples of the shrimp species were collected from local markets and field surveys operated with trawls similar to those used by fishermen. The mesh size of codend of the trawl nets was 15 mm.

The total length (TL, cm) of each individual was recorded in order to use the FAO-ICLARM Stock Assessment Tools II (FiSAT II) (Gayanilo *et al*., 2002). The length data were grouped into 1 cm size classes in order to have about 10 to 20 length-classes, as suggested by Gayanilo *et al.* (2002) for a proper implementation of the FiSAT analysis. The whole data were merged by month and considered as a single file representing one theoretical year and analyzed accordingly.

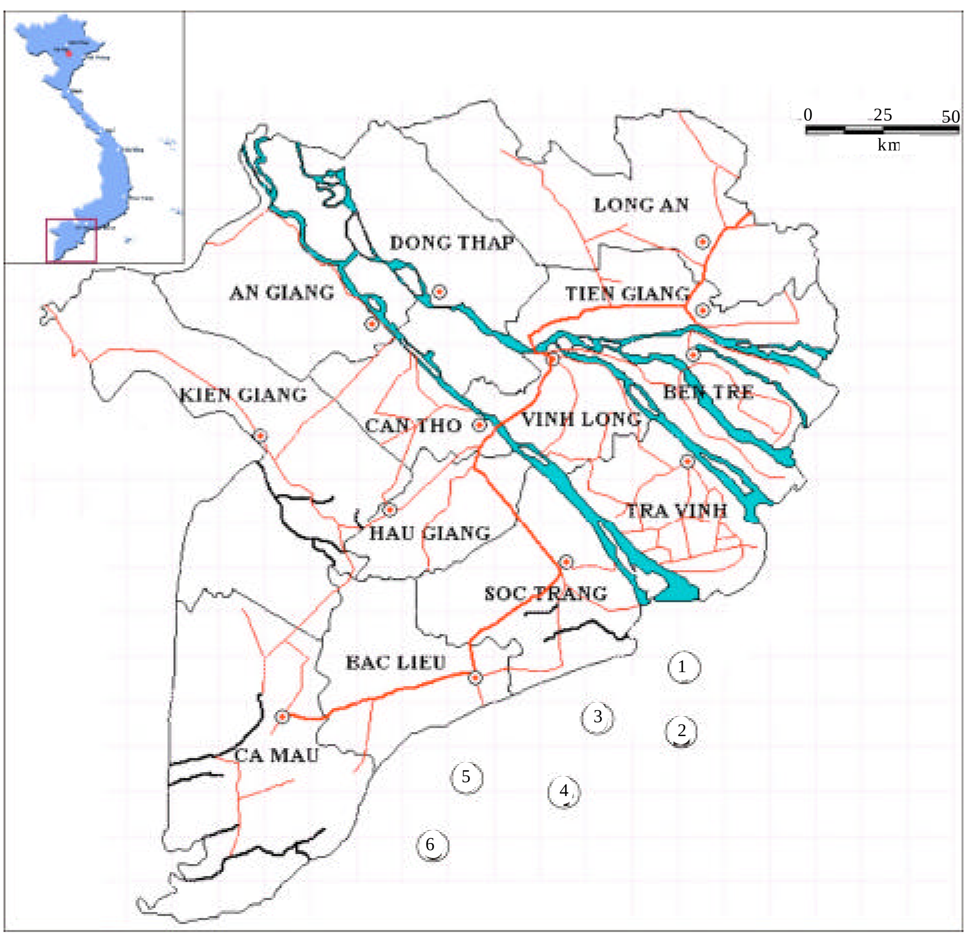

Fig. 1: The map showing sampling sites in the littoral marine waters of the Mekong Delta, South of Vietnam

Estimation of growth parameters: From the length-frequency distribution of the samples, ELEFAN I was used to obtain preliminary estimates of asymptotic length (L_∞) and growth constant (K) of the von Bertalanffy Growth Function (VBGF) following Gayanilo *et al.* (2002). Based on these preliminary estimates, a length-converted catch curve was constructed. Through the detailed analysis of the left part of the length-converted catch curve, the mean selection curve of the fishing gear was estimated. This selection curve was used to correct the length-frequency data for gear selection toward small fish (Pauly, 1980, 1984a, b). New estimates of L_∞ and K were obtained using the FiSAT II software from the analysis of the corrected length-frequency data. The best growth curve was then fitted on the basis of a non-parametric scoring from the goodness of a fit index, the so-called R_n-value (Gayanilo *et al*., 2002). In addition, the Phi-Prime index, ϕ' (Munro and Pauly 1983), was also used to compare the growth performance of species studied with other previous estimates available in the literature.

Estimation of mortality rates: The length-converted catch curve method (Gayanilo *et al*., 2002) was used for estimation of the instantaneous total mortality (Z). For obtaining an independent estimate of the natural mortality (M), Pauly's equation (Pauly, 1980) was employed. The mean annual environmental temperature was taken as 27°C as it is the average of the monthly water temperature. Fishing mortality (F) was derived as the difference between Z and M. Following the estimations of Z, M and F, the routine was also used to obtain the exploitation rate (E).

Probabilities of capture: The catch-curve analysis was extended to an estimation of probabilities of capture by backward projection of the number (N) that would be expected if no selectivity had taken place (Sparre, 1987).

Breeding activity pattern: By backward projection, along a trajectory defined by the VBGF, of the frequencies onto the time axis of a time-series of samples, plots showing the seasonal patterns of breeding activity were obtained. When appropriate, restructured samples were used as described by Moreau and Cuende (1991).

Relative yield-per-recruit: The relative yield-per-recruit analysis was performed incorporating probabilities of capture according to Pauly and Soriano (1986) and Gayanilo *et al*. (2002). For this purpose, the selection ogive estimated by detailed analysis of the ascending part of the length-converted catch curve was used.

RESULTS AND DISCUSSION

A total of 5311 shrimps were collected from September 2006 to August 2007. Total length of shrimp (from tip of rostrum to tip of telson) was taken to the nearest mm for length-frequency data. The original length-frequency distributions of eight species of shrimp were obtained and each set of the length-frequency data was analysed by using the FiSAT II software (Gayanilo *et al*., 2002) for determination the parameters of shrimp population such as growth parameters, mortality, gear selectivity and exploitation rates.

Growth parameters: The von Bertalanffy growth parameters (L_∞ and K) were estimated by using the Powell-Wetherall procedure and ELEFAN I (Gayanilo *et al*., 2002) for each species of shrimp and presented in Table 1. The results showed that the smallest size is *Parapenaeopsis gracillima* (L_∞ = 10.2 cm) and the largest size belongs to *Harpiosquilla harpax* (L_∞ = 21.0 cm). Garcia (1988) and Lalitha (1987) revealed that the maximum size of tropical penaeid prawns varies from 15-16 cm total length in some small penaeid species (*Metapenaeus* sp., *Xiphonpenaeus* sp.) to 30 cm in the giant tiger prawn (*Penaeus monodon*). The results indicated that eight species of shrimp grow very fast with K = 0.45-1.30 year^{-1}. In Kakinada (India), Lalitha (1987) also reported that growth rate (K) of three penaeid prawns ranged from 0.972 (*M. monoceros*) to 2.316 year^{-1} (*P. monodon*). In Northern Australia, prawns grow rapidly and most reach commercial size and reproductive maturity at the age of six months, although they take 9 to 12 months to reach the larger sizes (Dichmont *et al.*, 2007).

Mortality and demographic structure: The total mortality coefficients from length-converted catch curves indicate an annual estimate, for 1 year to the maximum observed theoretical age from 3 to 6 (Fig. 2a-h). The total mortalities and natural mortalities varied from 1.49 to 5.78 and from 1.17 to 2.61 year^{-1}, respectively. The fishing mortality was also highly variable, from 0.22 to 3.78 year^{-1} (Table 1). Results indicated that natural mortality was the major

Table 1: The results of the FiSAT analyses for eight species of commercial shrimp in the Mekong Delta

Species	L_{inf} (cm)	K (1/year)	Z	M	F	E
Haliporodes sibogae	12.8	0.77	2.27	1.88	0.39	0.17
Harpiosquilla harpax	21.0	0.89	3.23	1.80	1.43	0.44
Metapenaeus affinis	19.0	1.00	5.78	2.00	3.78	0.65
Metapenaeus brevicornis	15.5	0.87	3.35	1.93	1.42	0.42
Metapenaeus tenuipes	14.5	0.78	2.74	1.83	0.91	0.33
Parapenaeopsis cultrirostris	19.0	0.45	1.49	1.17	0.32	0.21
Parapenaeopsis gracillima	10.2	0.79	2.29	2.07	0.22	0.10
Parapenaeopsis maxillipedo	13.5	1.30	4.88	2.61	2.27	0.47

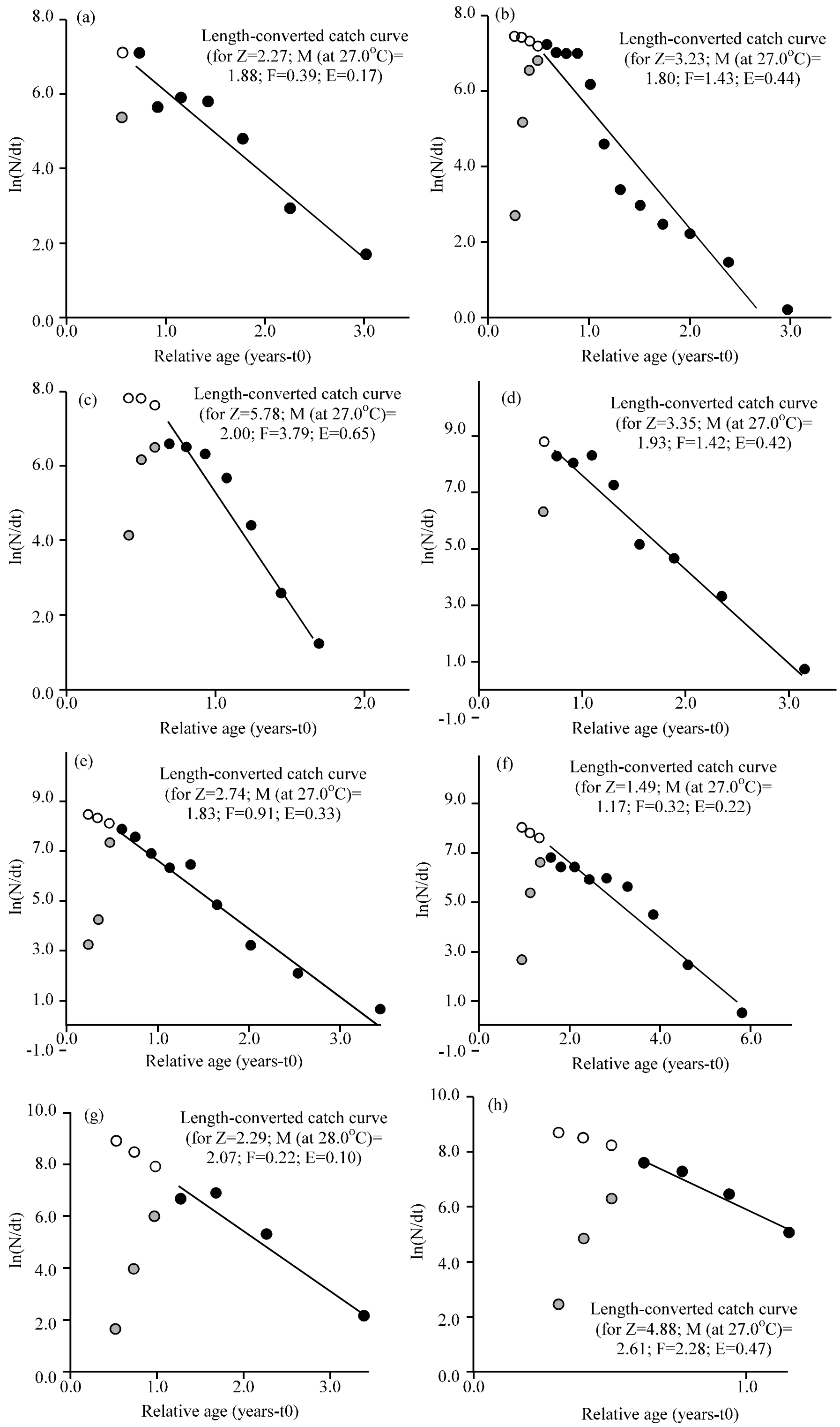

Fig. 2: Length-converted catch curve for some shrimp species distributed in the coastal areas of the Mekong Delta. Note: Only the black dots were considered for computation of total mortality. (a) *Haliporodes sibogae*, (b) *Harpiosquilla harpax*, (c) *Metapenaeus affinis*, (d) *Metapenaeus brevicornis*, (e) *Metapenaeus tenuipes*, (f) *Parapaenopsis cultrirostris*, (g) *Parapaenopsis gracillima* and (h) *Parapaenopsis maxillipedo*

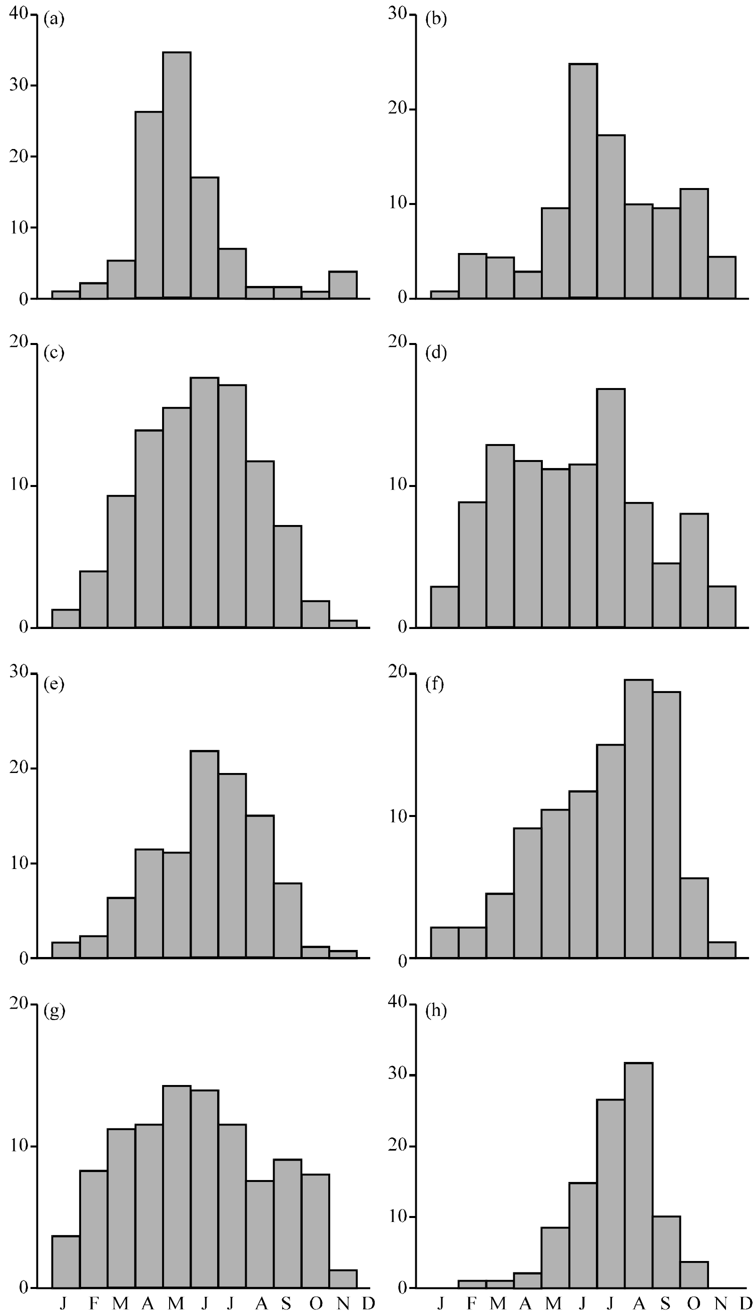

Fig. 3: Recruitment patterns of the shrimp species distributed in the Mekong Delta, (a) *Haliporodes sibogae*, (b) *Harpiosquilla harpax*, (c) *Metapenaeus affinis*, (d) *Metapenaeus brevicornis*, (e) *Metapenaeus tenuipes*, (f) *Parapaenopsis cultrirostris*, (g) *Parapaenopsis gracillima* and (h) *Parapaenopsis maxillipedo*

cause of death of *P.gracillima* and *P. cultrirostris*. Therefore, the current exploitation rate also varied from 0.10 to 0.65 (Fig. 2).

Recruitment pattern: The recruitment patterns showed that the shrimp species has the continuous recruitment with one peak in May for *H. sibogae* and *P. gracillima*; in June for *H. harpax*, *M. affinis* and *M. tenuipes*; in July for *M. brevicornis*; in August for *P. cultrirostris* and *P. maxillipedo* (Fig. 3a-h). The Mekong River is one of the largest rivers in the Southeast Asia; great volumes of sediment are carried towards the coastal areas during the

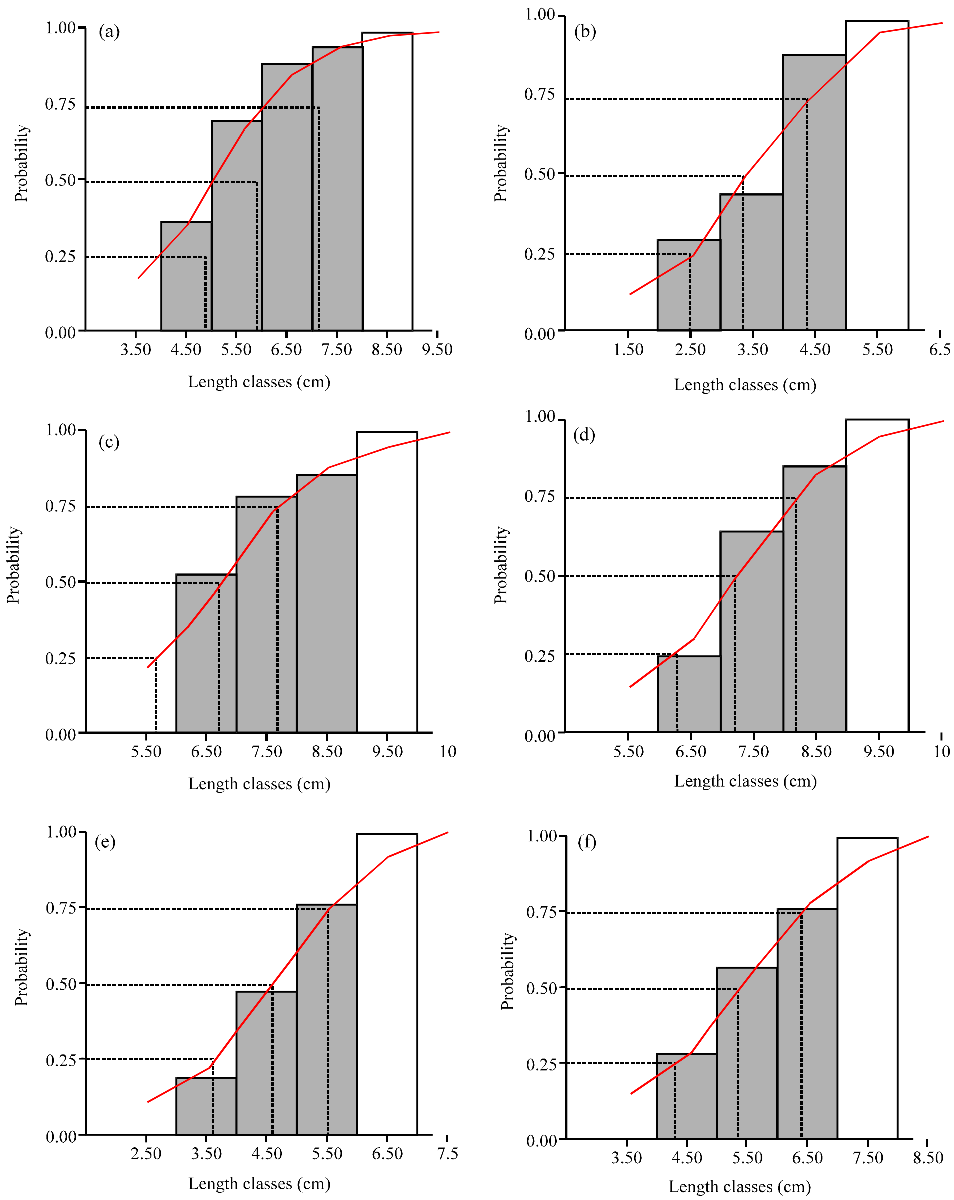

Fig. 4: The logistic selection curve for probability of capture, showing 25, 50 and 75% selection lengths of some shrimp species in the Mekong Delta. (a) *Harpiosquilla harpax*, (b) *Metapenaeus tenuipes*, (c) *Metapenaeus affinis*, (d) *Parapenaeopsis cultrirostris*, (e) *Parapenaeopsis gracillima* and (f) *Parapenaeopsis maxillipedo*

rainy season (from May to November); for that reason, the estuarine ecosystem provides a habitat for spawning and growing of aquatic species, especially for shrimp (Dinh *et al*., 2003, 2007). The results indicated that the shrimp species are usually entering the fishery during the raining season.

Gear selectivity: Except for *H. sibogae* and *M. brevicornis*, the analysis of probability of capture showed that length at first capture (L_c or L_{50}) of the commercial shrimp species fluctuated from 3.5 cm (*M. tenuipes*) to 7.5 cm (*P. cultrirostris*) (Fig. 4a-f). The results indicated that two groups of shrimp populations could be separated: one from which L_{50} is around 7.5 cm (*M. affinis* and *P. cultrirostris*) and another group is around 4.5 cm (*H. harpax*, *P. gracillima* and *P. maxillipedo*).

The relative yield-per-recruit analysis: Differences in optimization of the fisheries management strategies are

Table 2: Yield-per-recruit analysis and identification of the conditions for optimal fisheries management strategies for some shrimp species in the Mekong Delta

Species	$L_{inf.}$ (cm)	M/K	Current E	Optimal E	Current Lc (cm)	Optimal Lc (cm)
Harpiosquilla harpax	21.0	2.00	0.44	0.65	5.0	10.75
Metapenaeus affinis	19.0	2.00	0.65	0.65	6.5	9.5
Metapenaeus brevicornis	15.5	2.20	0.42	0.60	7.0	9.3
Metapenaeus tenuipes	14.5	2.40	0.33	0.58	3.5	6.5
Parapenaeopsis cultrirostris	19.0	2.60	0.21	0.60	7.5	9.0
Parapenaeopsis gracillima	10.2	2.60	0.10	0.55	4.5	5.5
Parapenaeopsis maxillipedo	13.5	2.00	0.47	0.55	5.5	6.7

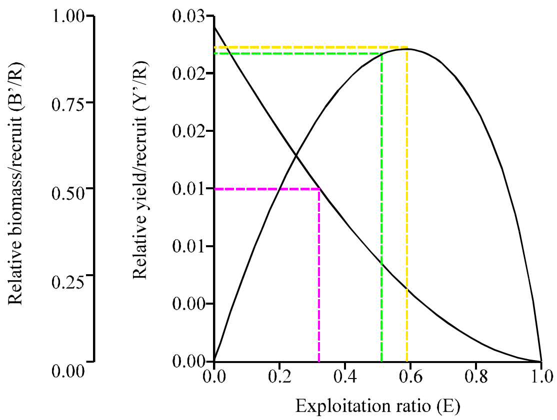

Fig. 5: An example (the case of *H. harpax*) of yield-per-recruit and average biomass-per-recruit models, showing levels of yield indices in some shrimps species in the Mekong Delta: MEY: Maximum economic yield and MSY: maximum sustainable yield

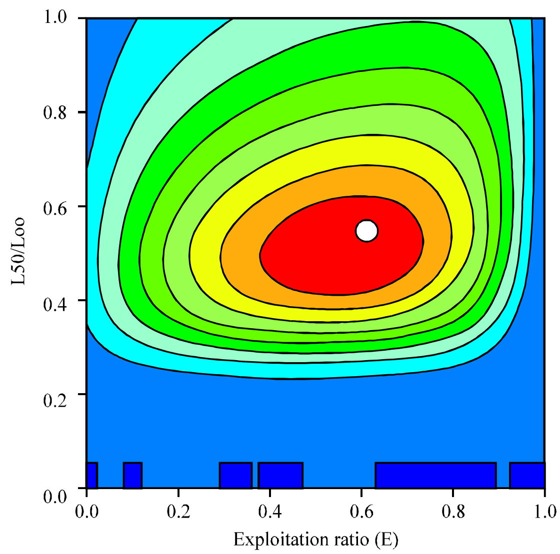

Fig. 6: An example (the case of *P. maxillipedo*) of isopleths, showing the optimum fishing activity both in terms of fishing effort and size of first capture (depicted with a circle in the central curve) of some shrimp species in the Mekong Delta

simultaneously identified by the relative yield-per-recruit analysis performed incorporating the probabilities of capture and fishing gear selectivity curve (Table 2 as illustrated with Fig. 5 and 6). It revealed that with the fishing gear currently in use, the maximum sustainable yield would be reached for an exploitation rate higher than the current one for each population. However, the current length at first capture (L_c) was lower than the optimal length at first capture in all the shrimp species (Table 2). Therefore, the size of first capture should be increased for every population.

To achieve the MSY target while keeping in mind the uncertainties associated with estimated growth rate, natural mortality and fishing mortality estimates, this study recommends that the shrimp species would be exploited at larger sizes than presently (Table 2). This would mean that the mesh size of the fishing gear would have to change and correspond to the fishing grounds; and fishing efforts in the shrimp fishery should be managed as well. Dichmont *et al.* (2007) also stated that the input controls such as size of gear and number of fishing days, rather than output controls such as catch quota, are the basis for management of shrimp fisheries in Australia.

However, the research areas have managed under traditional ownership by an adjacent community group and the shrimp stocks are regarded as a common resource. Therefore, increase in mesh size of the fishing gears may be difficult to implement and can probably only be considered if management of the fishery is developed by and for the local communities. Furthermore, the difficulties involved in management of shrimp resource are also related to the number and types of user groups. Therefore, the community-based co-management approach should be applied to the fishery for sustainable development of the shrimp stocks; because this approach focuses not only on the protection of habitat and resource management, but also on community and economic development.

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