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Some Ecological Considerations for Stock Enhancement of Commercially Important Prawns along the Coastal Waters of Southwest Taiwan

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SOME ECOLOGICAL CONSIDERATIONS FOR STOCK ENHANCEMENT OF COMMERCIALLY IMPORTANT PRAWNS ALONG THE COASTAL WATERS OF SOUTHWEST TAIWAN[1]

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ABSTRACT

The application of stock enhancement technology to improve the production of coastal fisheries has drawn much attention in Taiwan in recent years. To promote this venture, the coastal waters along the southwest of Taiwan were chosen as an experimental area for stock enhancement of prawns. Ecological information, including species composition, distribution, reproduction, recruitment, growth, food habits, from catch and effort data, prawn samples, and tagging and recapturing experiments, was collected from July 1982 to December 1986. Based on findings, the strategy of stock enhancement of prawns in Taiwan's southwestern coastal waters was developed.

INTRODUCTION

The use of stock enhancement technology to improve coastal fishery production has been practiced in Japan since 1963 (Oshima 1984). In 1985, the Japan Sea Farming Association and prefectural government released into the sea more than 2,423 million seed of 12 aquatic species with high commercial value. Among them were about 292 million postlarvae of kuruma prawn, *Penaeus japonicus* (Japan Sea Farming Association 1987). The survivors from this release augmented natural stocks in natural waters. According to Uno (1984), many experimental releases of postlarvae in natural waters have proven that release of hatchery reared prawns can be successful.

To have an effective release program, it is necessary to establish: (1) the target species, (2) techniques for mass production of seed, (3) optimum seed size for release, (4) the number of seed to be released, (5) ideal season of release, (6) best sites for release, (7) an effective method of release, (8) a conservation system to protect the released animals and, (9) commercial harvest must increase and spawners must increase in numbers (Kurata 1972; Oshima 1984).

The establishment of stock enhancement techniques to augment the production of coastal fisheries has drawn much attention in Taiwan. To promote this venture, the Tungkang Marine Laboratory (TML) of the Taiwan Fisheries Research Institute (TFRI) selected the coastal waters along the southwestern coast of Taiwan as an experimental area for prawn releases. A series of ecological studies on commercially important prawns in this experimental area was carried out from July 1982 to December 1986. Some of the results, including species composition, distribution, reproduction, recruitment, food and

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feeding, and the recapture of tagged subadult *P. monodon*, are presented in this paper. This is the basis for a proposed strategy of prawn enhancement in Taiwan's southwestern coastal waters.

MATERIALS AND METHODS

The study area is along the southwest coast of Taiwan, between latitude 22°05′ and 22°39′N and longitude 120°12′ and 120°40′ E (Fig. 1).

Fishery data were collected from commercial trawlers (5.5 t ; 22 hp) operating in the study area from July 1982 to December 1986. The methods of data collection and processing were the same as those described by Su and Liao (1984). Monthly catch per unit effort (CPUE) was calculated for each 2×2 square kilometer statistical block. A total of 6,340 pond-reared subadults of *P. monodon* were also weighed and tagged with an Anchor-type tag (Su and Liao, unpublished data) and released a total of 16 times along the coast of Tungkang between August 1983 and June 1984.

Prawn samples were collected monthly from boats operating in the study area from July 1982 to December 1984. To estimate the emigration of prawns from Dapong Bay (Fig. 1) into the sea, samples were taken from a filter net at the mouth of the bay during

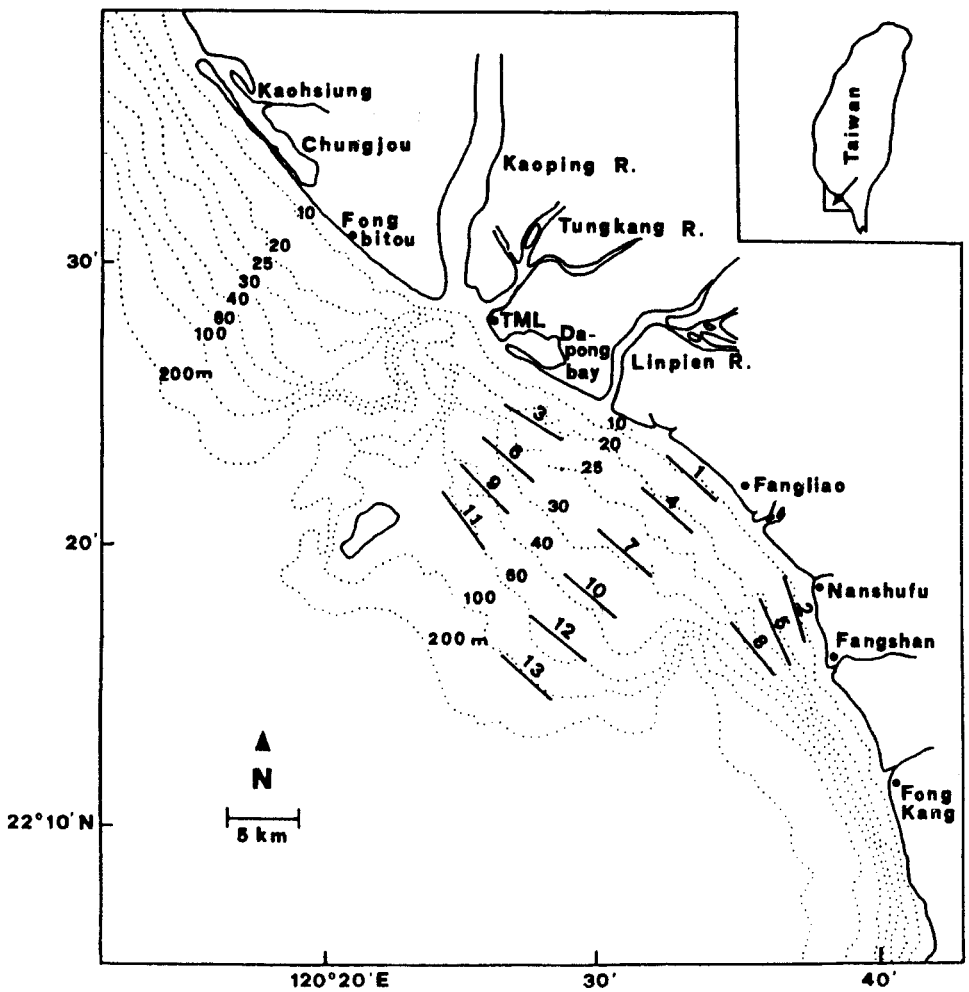

Fig. 1. Map showing the study area, depth contour and thirteen sites for experimental trawlings.

every new moon, first quarter, full moon, and last quarter moon phase from August 1984 to December 1986. In addition, 13 sampling sites were selected in the coastal zone (Fig. 1). Experimental trawlings were conducted monthly at each site by a chartered prawn trawler (5.5 t; 22 hp) from October 1984 to October 1985.

After transfer to TML, the prawns were identified and counted by species. The carapace length (CL) of each specimen was measured to the nearest 0.1 mm, and the body weight (BW) to the nearest 0.01 g. Sex was determined for each individual, and in the case of females a visual estimate of ovarian development was made. The fullness of each stomach was determined visually with a 0-4 point system. Stomach contents were preserved in 5% formalin. For stomach analysis, the contents of each stomach were rinsed into a petri dish and examined under binocular microscope. Both the occurrence and the points method (Hyslop 1980; Gunn and Milward 1985) were then employed to elucidate the spectrum of food ingested. In the former method, the number of stomachs in which each food type occurred was expressed as a percentage of total number of stomachs containing food. In the latter method, the volume of each food type was visually estimated and expressed as a percentage of the total stomach content volume.

RESULTS

Species composition

A total of 20 species belonging to seven genera were collected through trawling (Table 1). Of the 20 species, *Metapenaeopsis barbata, Metapenaeus ensis, Penaeus semisulcatus, P.*

Table 1. Prawn species taken from combined collections at 13 survey sites from October 1984 to October 1985*

Species	Biomass (g)	%	Rank
Metapenaeopsis barbata	35,483	36.63	1
Metapenaeus ensis	61,814	17.36	2
Penaeus semisulcatus	10,498	10.84	3
Penaeus monodon	9,647	9.96	4
Parapenaeopsis cornuta	8,890	9.18	5
Trachypenaeus curvirostris	3,085	3.18	6
Metapenaeus affinis	2,509	2.59	7
Parapenaeus longipes	2,494	2.57	8
Solenocera melantho	1,796	1.85	9
Parapenaeopsis hardwickii	1,678	1.73	10
Penaeus penicillatus	1,434	1.48	11
Penaeus japonicus	870	0.90	12
Parapenaeopsis sculptilis	428	0.44	13
Penaeus sp.	411	0.42	14
Penaeus marginatus	276	0.29	15
Penaeus canaliculatus	208	0.22	16
Metapenaeus joyneri	192	0.20	17
Metapenaeus moyebi	124	0.13	18
Trchypenaeus anchoralis	23	0.02	19
Penaeus longistylus	14	0.01	20
Total	6,8749	100	

* Data are based on 156 number of samples obtained from a chartered prawn trawler.

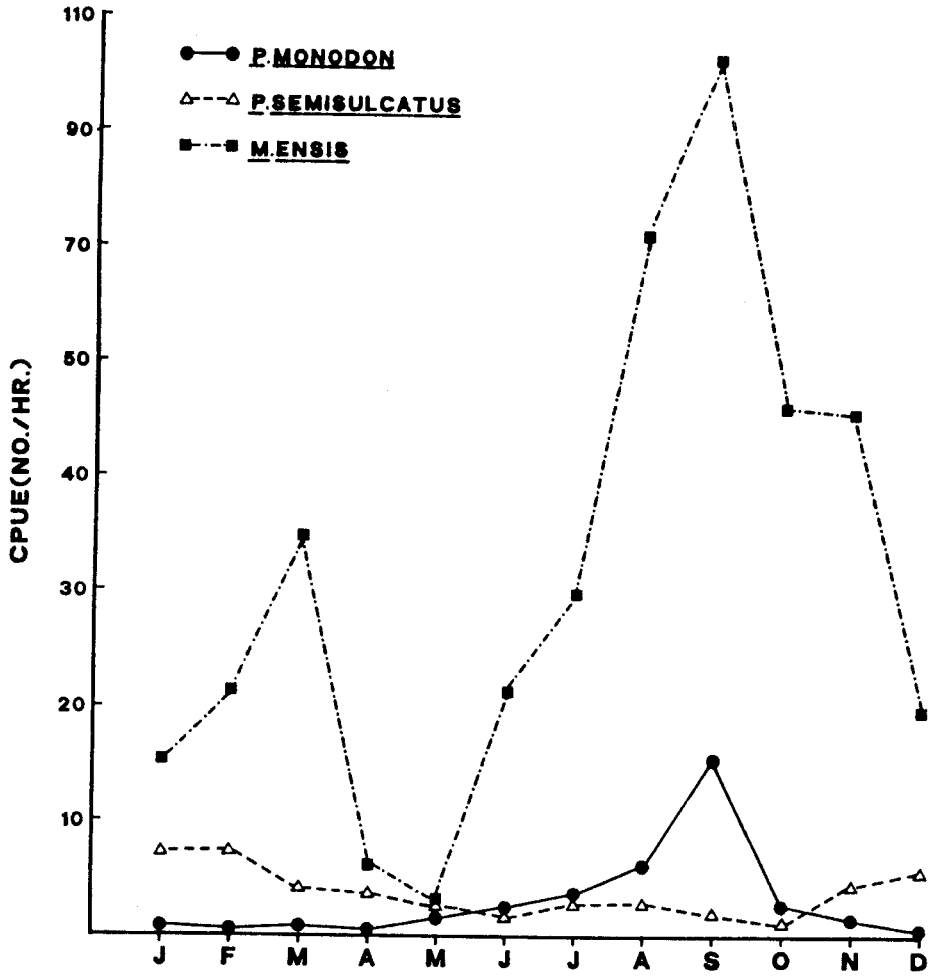

Fig. 2. Seasonal variation in relative abundance of *P. monodon*, *P. semisulcatus* and *M. ensis* in waters along southwest Taiwan from July 1982 to December 1986 as indicated by monthly change in catch per unit effort.

monodon, and *Parapenaeopsis cornuta* accounted for 83.97% of the total biomass. Of particular commercial importance are *P. monodon*, *P. semisulcatus* and *M. ensis*. Fig. 2 shows the relative abundance by month of these three species. *M. ensis* was the most abundant, with peaks from February to March and August to November. Second in abundance was *P. monodon* with a peak from August to September. *P. semisulcatus* occurred mainly from November to February.

Distribution

P. monodon was found mainly from July to September in waters from the mouth of Dapong Bay to Nanshufu at depths less than 25 m (Fig. 3). Spawners were mainly caught in May in waters off the estuary of Kaoping River at depths of 30-40 m and in waters between the estuary of Linpien River and Nanshufu at depths of 20-40 m from September to November (Fig. 4). The composition of carapace lengths by depth is shown in Fig. 7. Larger prawns were in general found in deeper waters.

P. semisulcatus occurred mainly from November to March in waters between Fonbitou and Fangliao at depths of 20-40 m and in July, between the estuary of Linpien River and Fangliao at depths of 20-30 m (Fig. 5). Larger prawns in general occurred in deeper offshore waters (Fig. 7).

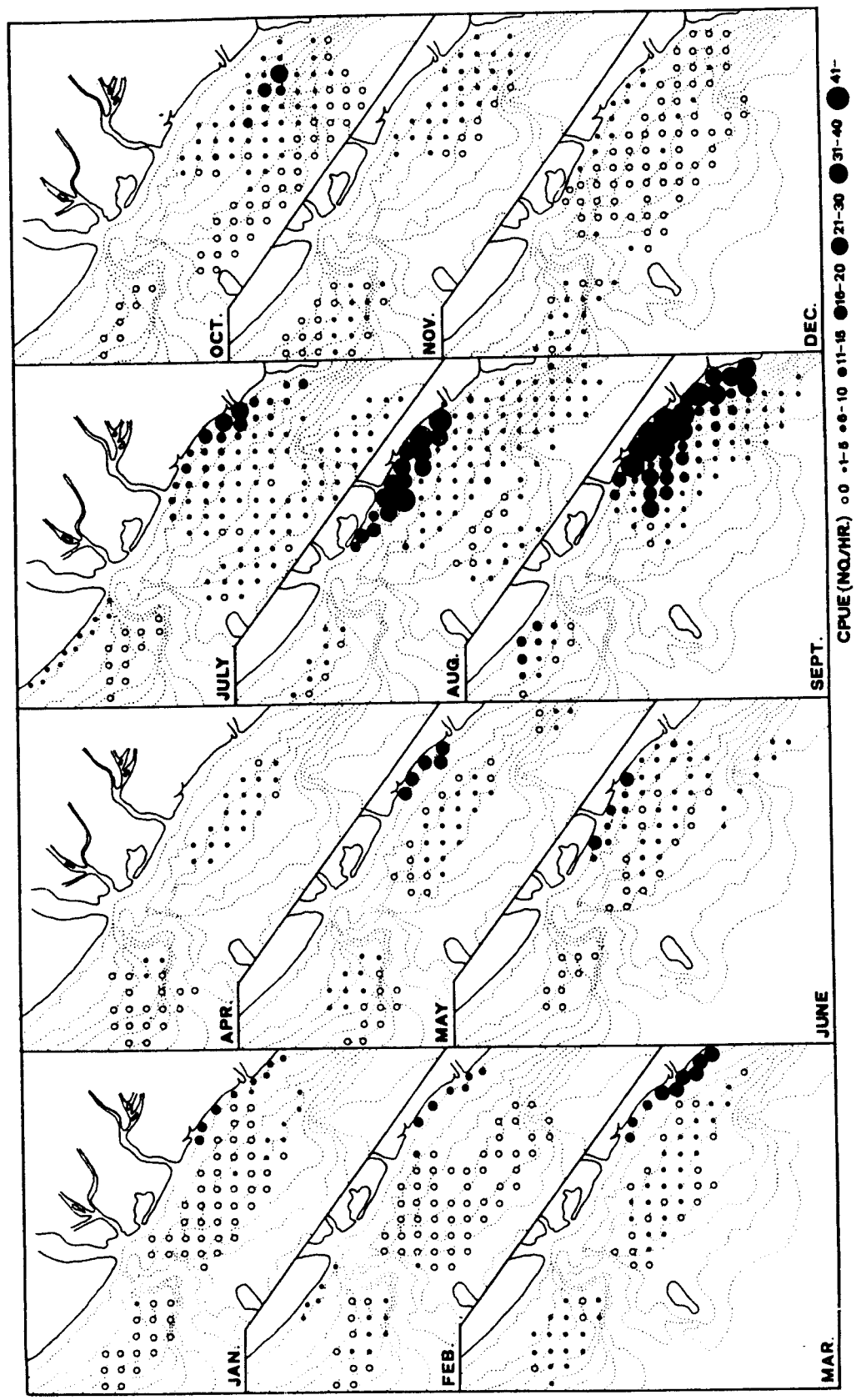

Fig. 3. Distribution of CPUE (in number per hour) of *P. monodon* in waters off southwest Taiwan based on combined data of catch and effort from July 1982 to December 1986.

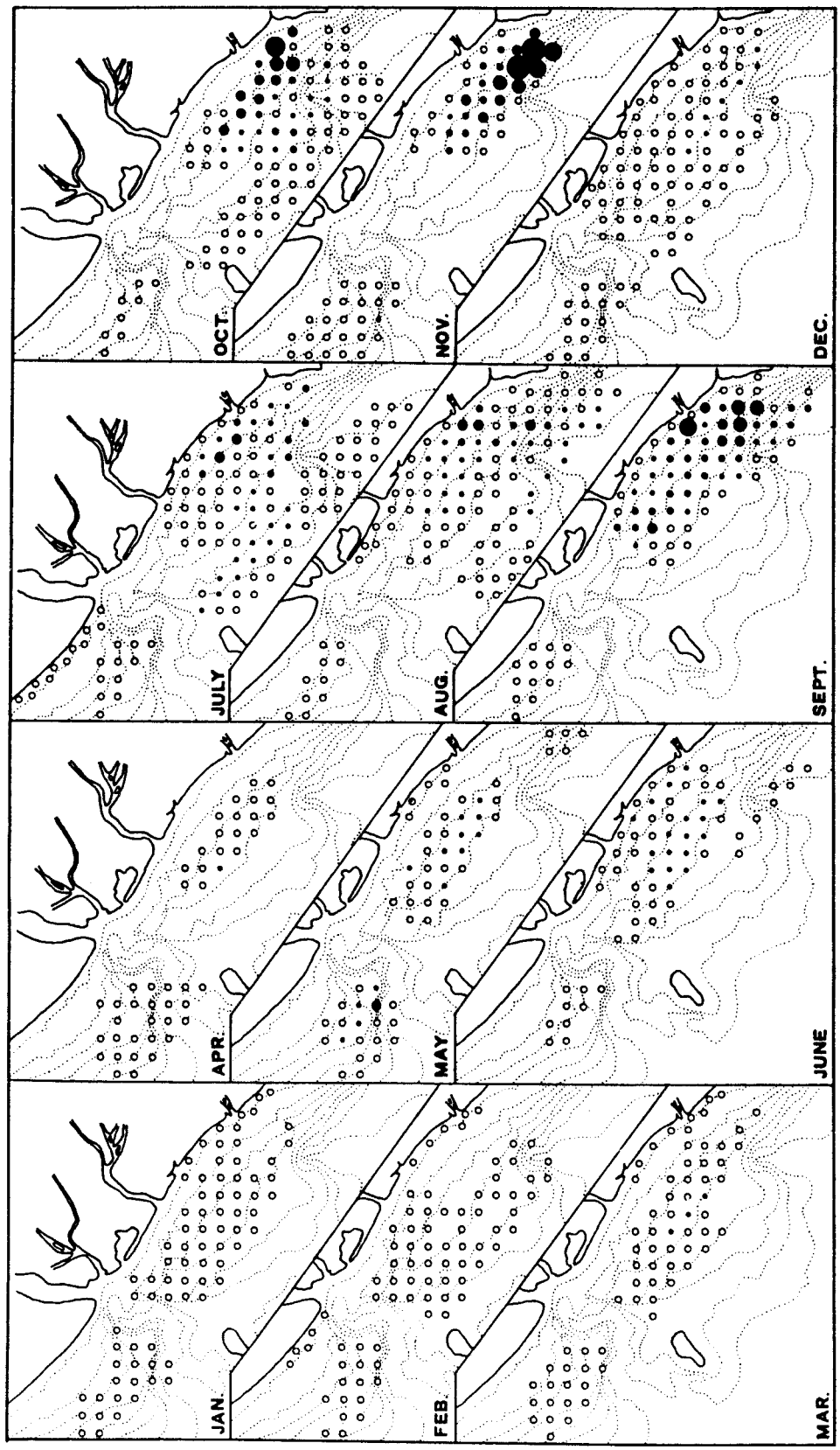

Fig 4. Distribution of CPUE (in number per 10 hours) of *P. monodon* spawners in waters off southwest Taiwan based on combined data of catch and effort from July 1982 to December 1986.

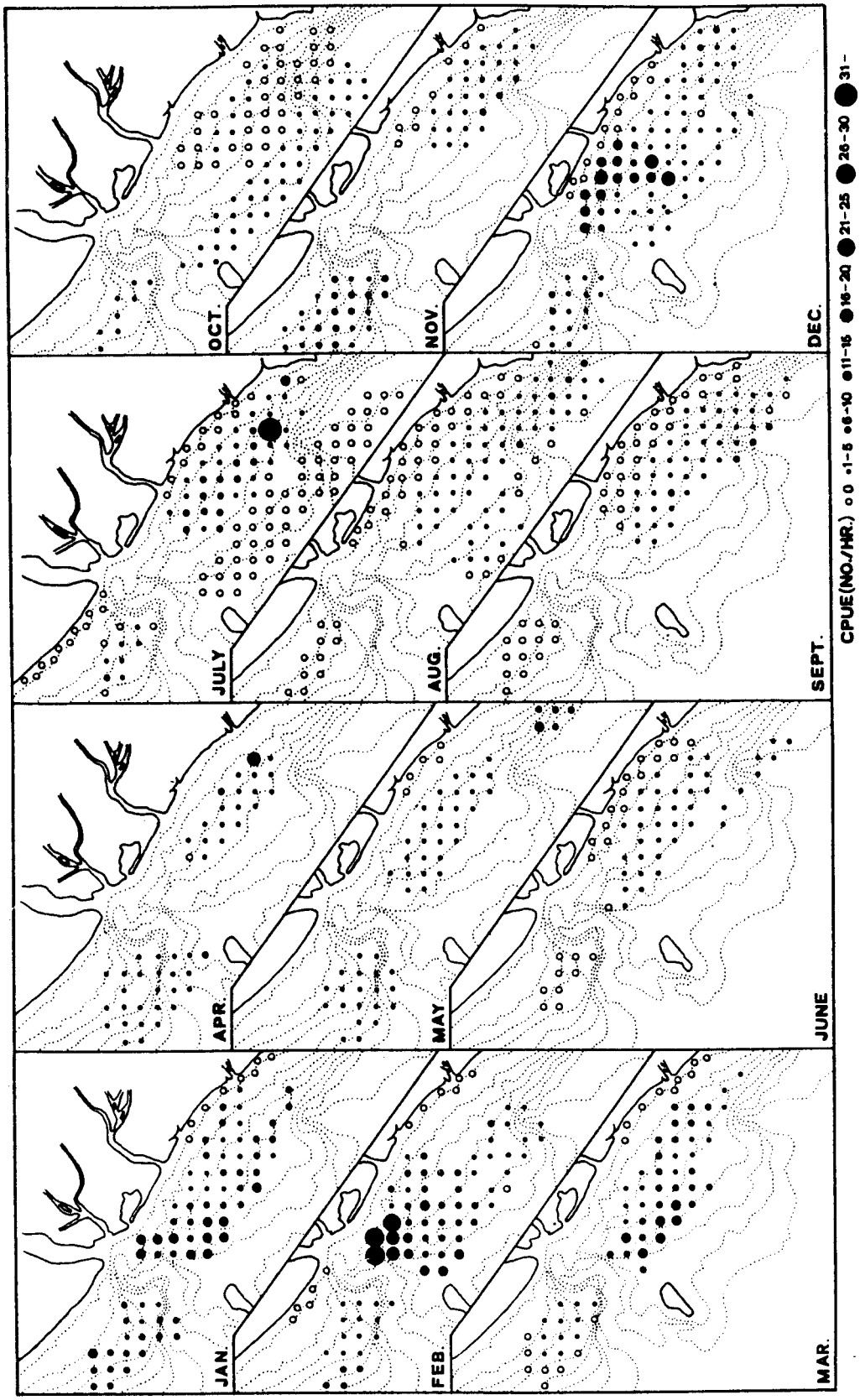

Fig. 5. Distribution of CPUE (in number per hour) of *P. semisulcatus* in waters off southwest Taiwan based on combined data of catch and effort from July 1982 to December 1986.

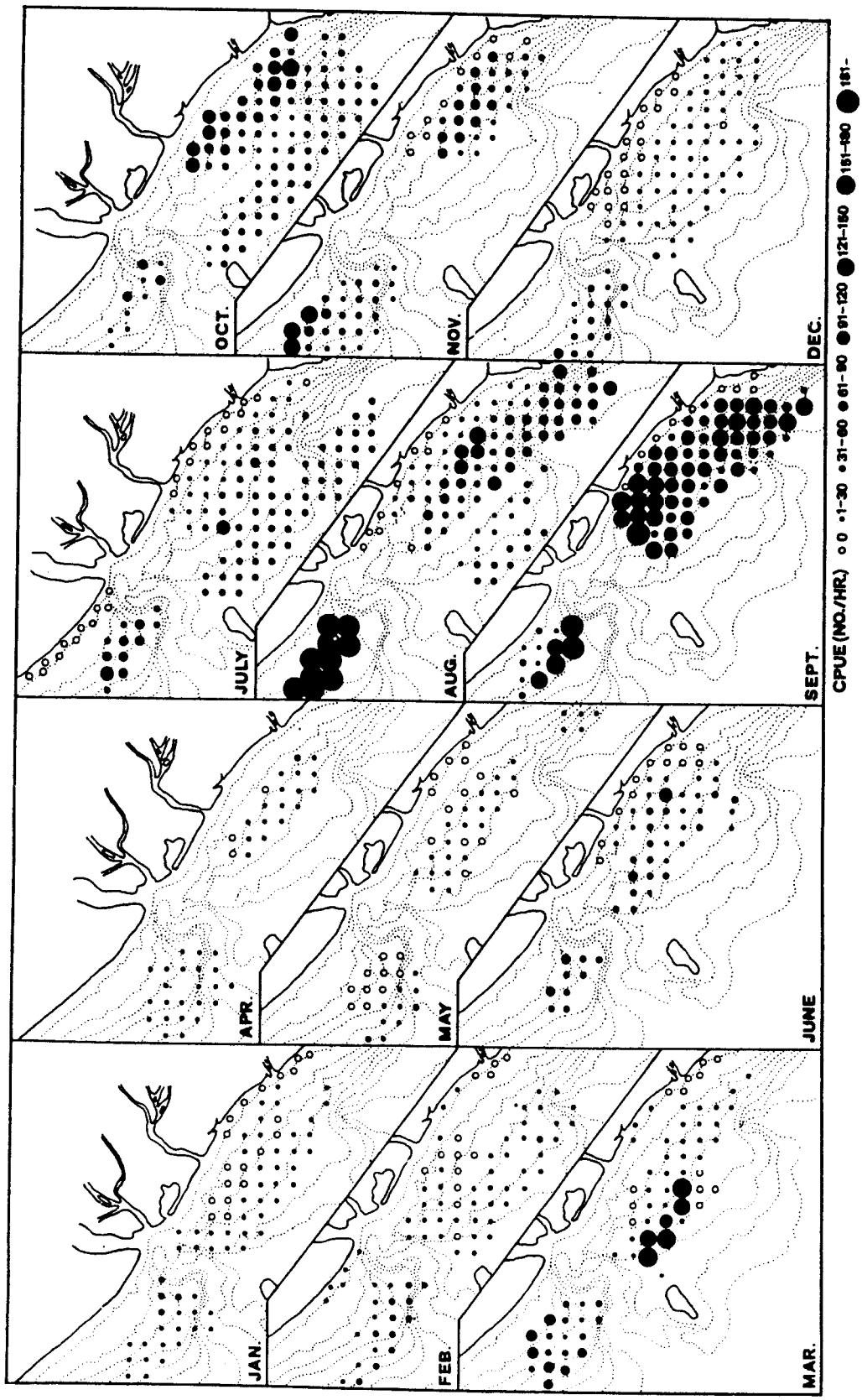

Fig. 6. Distribution of CPUE (in number per hour) of *M. ensis* in waters off southwest Taiwan based on combined data of catch and effort from July 1982 to December 1986.

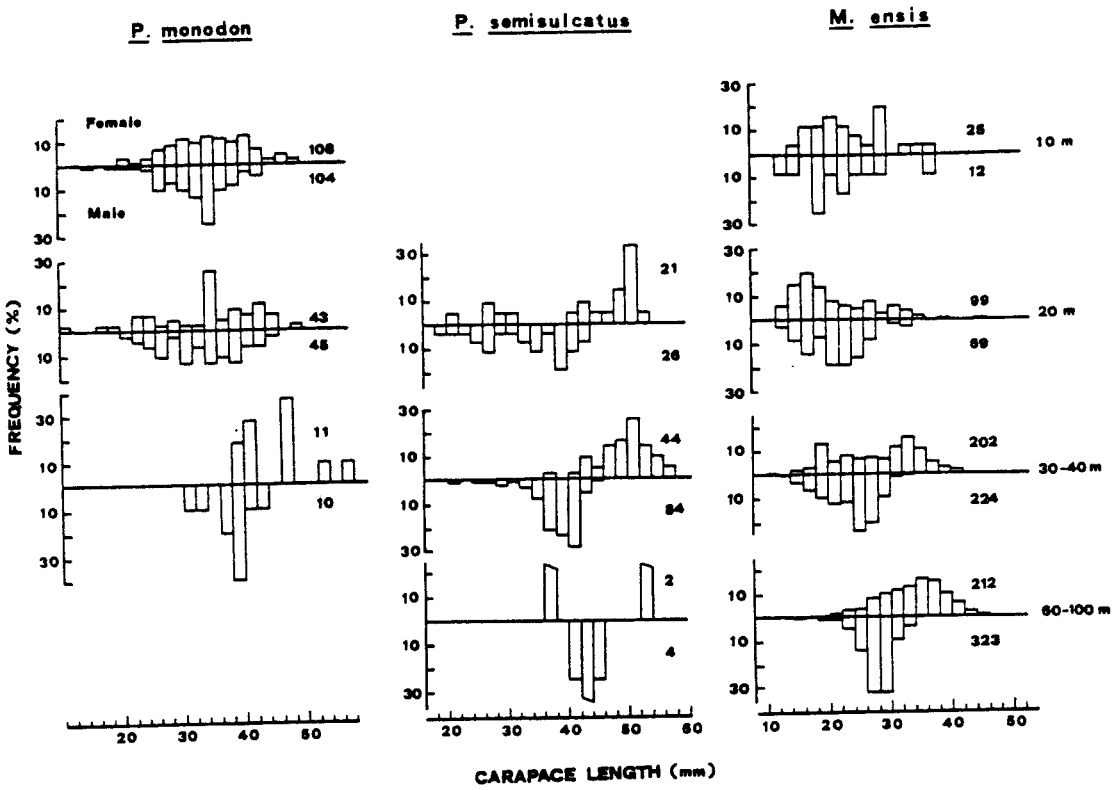

Fig. 7. Frequency distribution of carapace length of *P. monodon*, *P. semisulcatus* and *M. ensis* by water depth and sex in waters off southwest Taiwan from October 1984 to October 1985. The number in the figure indicates samples size.

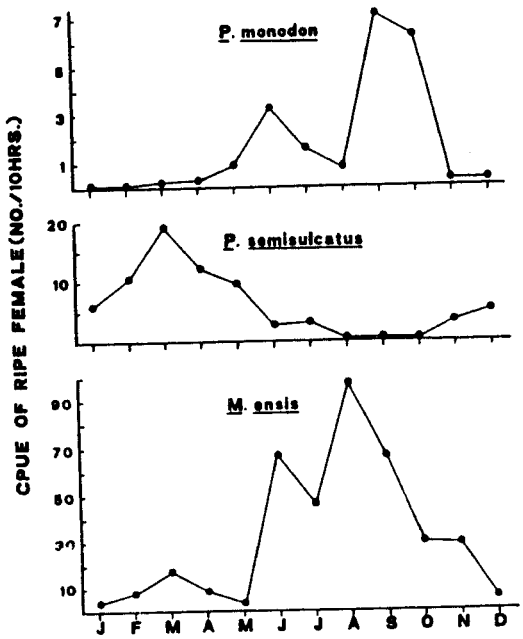

Fig. 8. Seasonal change in CPUE of *P. monodon*, *P. semisulcatus* and *M. ensis* spawners (in number per 10 hours) in waters off southwest Taiwan based on combined data from July 1982 to December 1986.

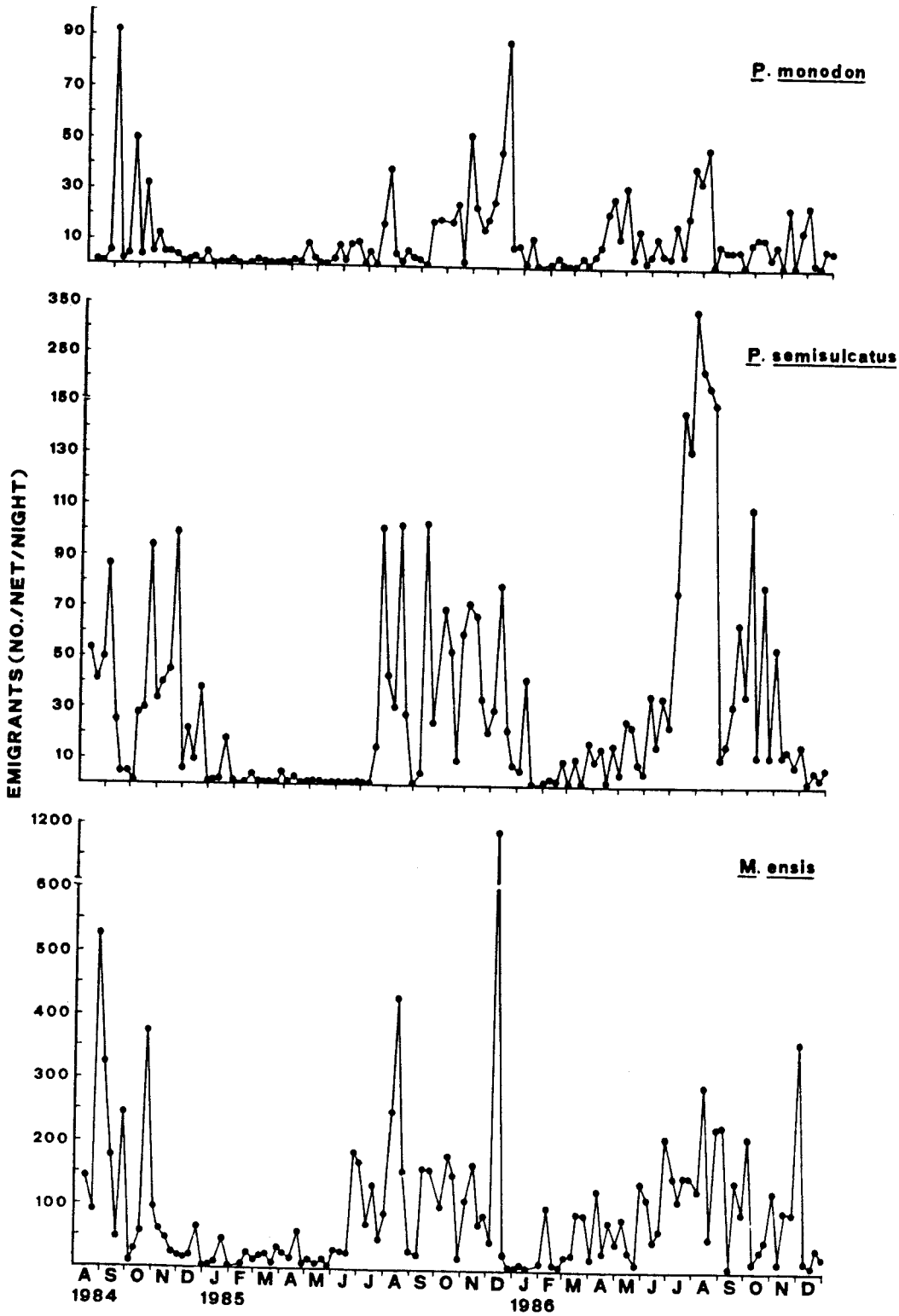

Fig. 9. Fluctuation in number of *P. monodon*, *P. semisulcatus* and *M. ensis* caught per net per night at the mouth of Dapong Bay from 1984 to 1986, indicating the seasonal pattern of emigration.

M. ensis were caught mainly from August to November in waters between Chungjou and Fanshan at depths of 20-60 m (Fig. 6). Larger prawns in general were caught in deeper offshore waters (Fig. 7).

Reproduction

Reproductive seasonality, as suggested by the presence of gravid females among the catches, is presented in Fig. 8. *P. monodon* reproduces in June, September and October, *P. semisulcatus* reproduces between February and May and *M. ensis* reproduces from June to September.

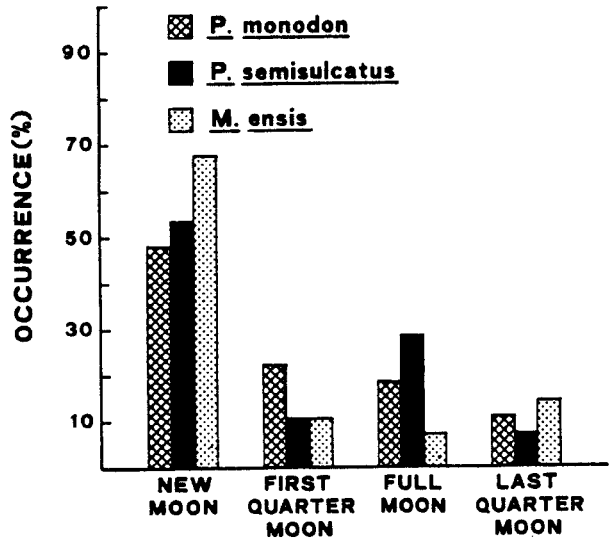

Fig. 10. Relationship of occurrence of peak emigration and moon phase for *P. monodon*, *P. semisulcatus* and *M. ensis* caught at the mouth of Dapong Bay from August 1984 to December 1986.

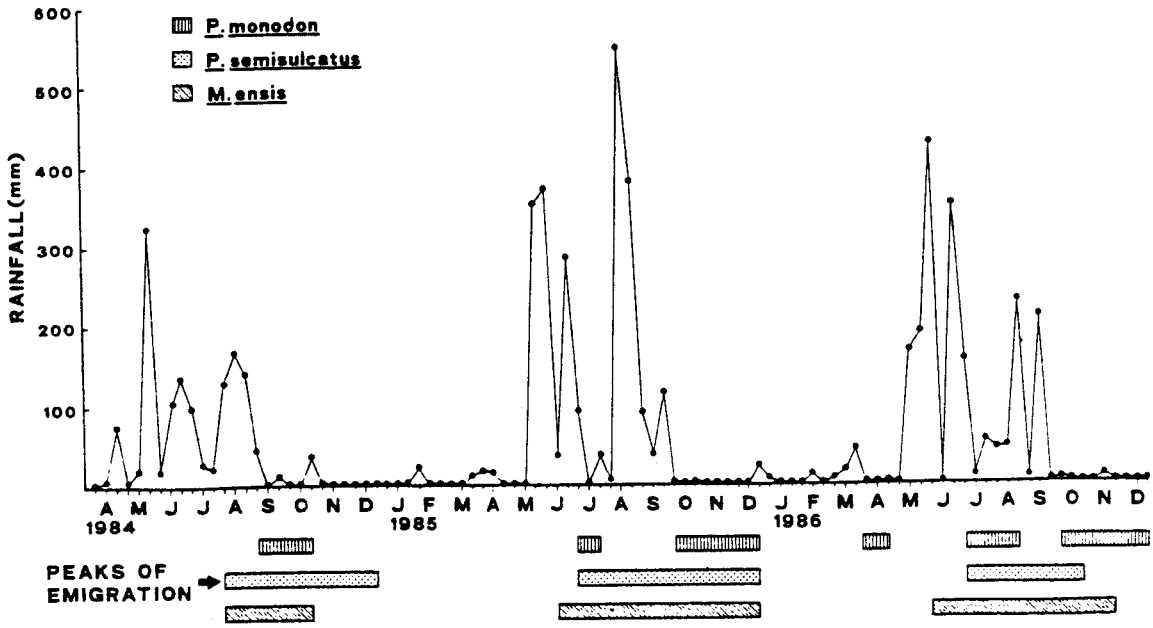

Fig. 11. Relationship between rainfall and peaks of emigration for *P. monodon*, *P. semisulcatus* and *M. ensis*, respectively, caught at the mouth of Dapon Bay.

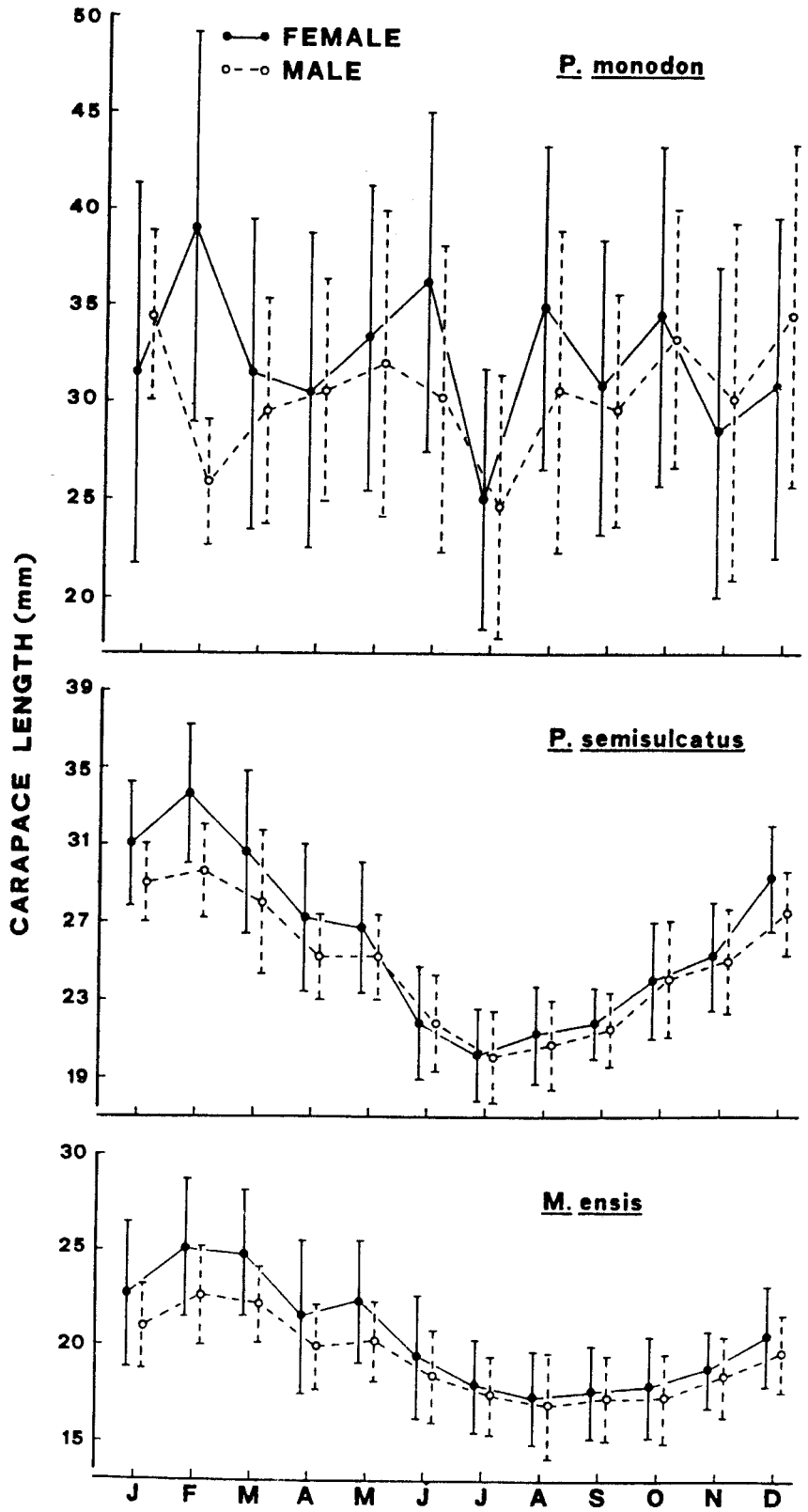

Fig. 12. Seasonal variation in the carapace length (X±1SD) of the emigrating prawns trapped at the mouth of Dapong Bay from August 1984 to December 1986.

Recruitment

The emigrations of *P. monodon*, *P. semisulcatus* and *M. ensis* from Dapong Bay were used as a basis to estimate recruitment of these species into the open coastal fishery.

P. monodon emigrated to waters along the open coast from April to December (Fig. 9), mostly during the new moon phase (Fig. 10) 1-2 months after the rainy season (Fig. 11). The mean carapace length of emigrating prawns ranged from 25.0 to 39.0 mm for females and 24.6 to 34.5 mm for males. Early emigrants were usually the smaller ones which migrate mainly in March, July, September and November (Fig. 12).

P. semisulcatus emigrated to open coastal waters from July to December (Fig. 9), mostly during the new moon or full moon phase (Fig. 10), 1-2 months after the rainy season (Fig. 11). The mean carapace length of emigrating prawns ranged from 20.7 to 33.6 mm for females and 20.4 to 29.6 mm for males. Early emigrants were usually the smaller ones which migrate mainly from June to August (Fig. 12).

M. ensis emigrated to open coastal waters from June to December (Fig. 9), mostly during the new moon phase (Fig. 10), 1-3 months after the rainy season (Fig. 11). The mean carapace length of emigrating prawns ranged from 17.8 to 25.0 mm for females and 17.4 to 22.6 mm for males. Early emigrants were usually the smaller ones which migrate mainly from June to October (Fig. 12).

Food and feeding

Stomach contents examined consisted of thoroughly masticated food items, and identification of food types was based on fragmented remains. The stomach contents were classified into nine categories (Table 2).

About 60% of *P. monodon* prawns from Dapong Bay had empty stomachs whereas those from open coastal waters had only 26% empty (Fig. 13). Based on frequency of occurrence, the order of relative importance of food items was crustaceans, detritus, molluscs and fish for prawns from Dapong Bay; and detritus, crustaceans, sand granules and molluscs for prawns from the open coast (Fig. 14). Volumetrically, the order became crustaceans, fish, detritus and chaetomorphs; and detritus, crustaceans, sand granules and molluscs, respectively (Fig. 15).

About 60% of *P. semisulcatus* prawns from Dapong Bay had empty stomachs, whereas for those from open coastal waters had only 24% empty (Fig. 13). Based on frequency of occurrence, the order of relative importance of food items was crustaceans, molluscs, detritus and sand granules for prawns from Dapong Bay; and detritus, sand granules and crustaceans for prawns from the open coast (Fig. 14). Volumetrically, the order was the same as that described above (Fig. 15).

Table 2. Categories of materials found in the stomachs of *P. monodon*, *P. semisulcatus* and *M. ensis*

Item	Abbreviation	Contents
Crustaceans	CR	Limbs, eyes, setae, body fragments of crustaceas
Molluscs	MO	Shell fragments of gastropods and bivalves
Fish	FI	Scales, vertebrae, bones of small fish
Polychaets	PO	Setae, jaws, body fragments
Radiolarians	RA	Fragmented skeletal capsule
Sponges	SP	Spicules
Chaetomorphs	CH	Filaments
Detritus	DE	Unrecognizable, decaying fragments
Sand granules	SA	Particles of very fine sand

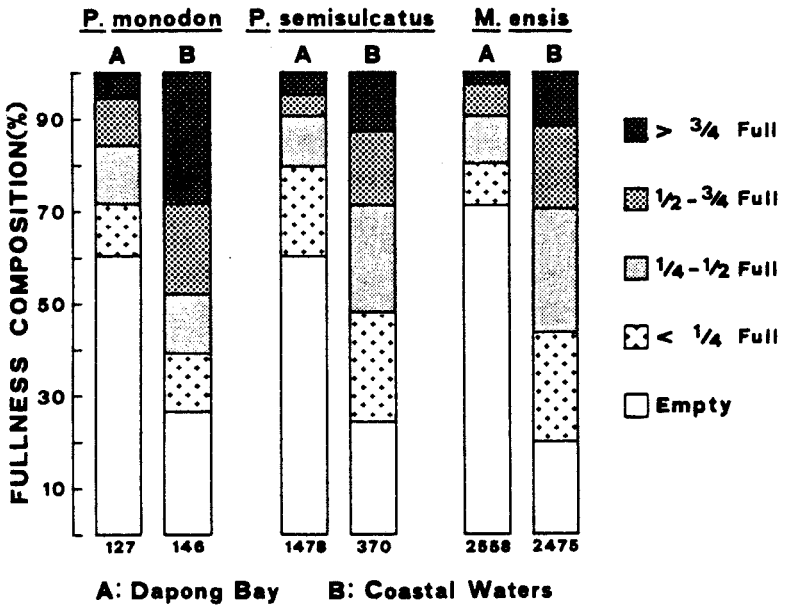

Fig. 13. Fullness of stomach by species for *P. monodon*, *P. semisulcatus* and *M. ensis*, respectively, from July 1982 to December 1986. The number under the figure indicates sample size.

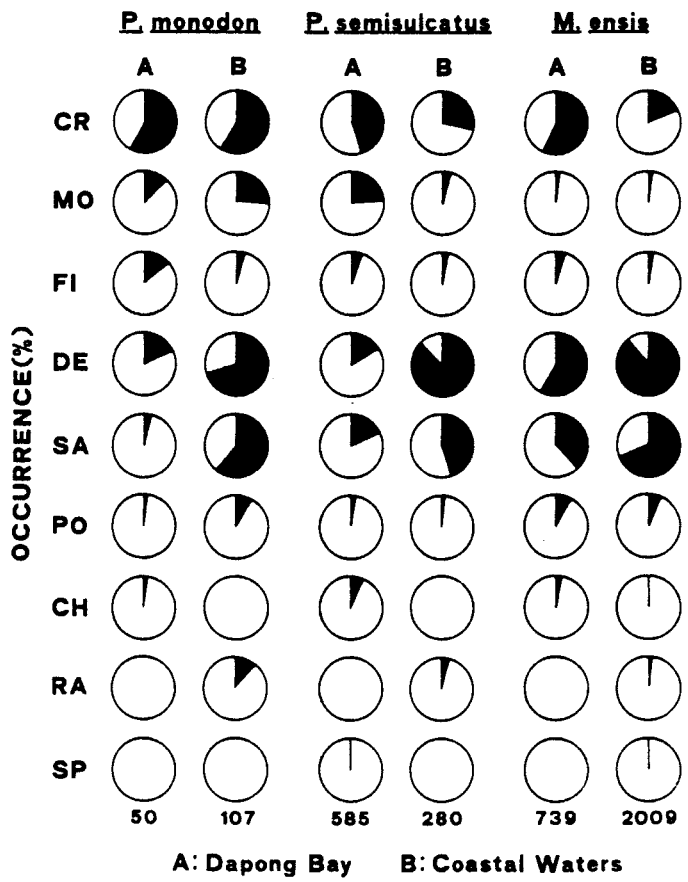

Fig. 14. Occurrence of different food items (shaded area) in the stomach of *P. monodon*, *P. semisulcatus* and *M. ensis* sampled from July 1982 to December 1986. The number under the figure indicates sample size. For abbreviation of various food items, see Table 2.

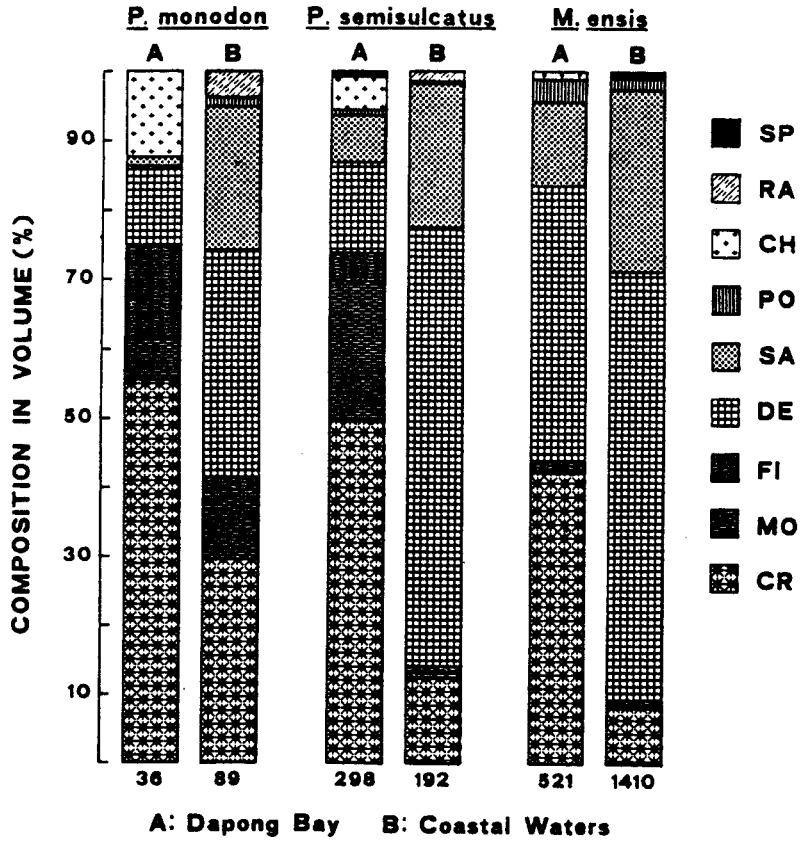

Fig. 15. Percentage volume of different food items in *P. monodon*, *P. semisulcatus* and *M. ensis* sampled from July 1982 to December 1986. The number under the figure indicates sample size. For abbreviation of various food items, see Table 2.

Table 3. Data of recaptured subadults of *P. monodon* released from Tungkang coast from August 1983 to June 1984

Data of release	No. of prawns released	No. of prawns recaptured	Recapture rate %	Sources of prawns for release
1983 Aug. 14	500	3	0.60	Private farm
Aug. 24	169	7	4.14	Private farm
Aug. 25	105	2	1.90	Private farm
1984 Jan. 13	283	2	0.70	Private farm
Jan. 14	425	11	2.59	Private farm
Jan. 26	276	13	4.71	Private farm
Feb. 25	488	1	0.20	Private farm
Mar. 7	580	3	0.52	Private farm
Mar. 10	575	2	0.35	Private farm
Mar. 11	392	14	3.57	Private farm
Mar. 15	581	2	0.34	Private farm
Apr. 3	567	3	0.53	Private farm
Apr. 12	477	2	0.42	Private farm
May 3	604	1	0.17	Private farm
May 23	119	6	5.04	Private farm
June 6	199	31	15.57	TML
Total	6340	103		

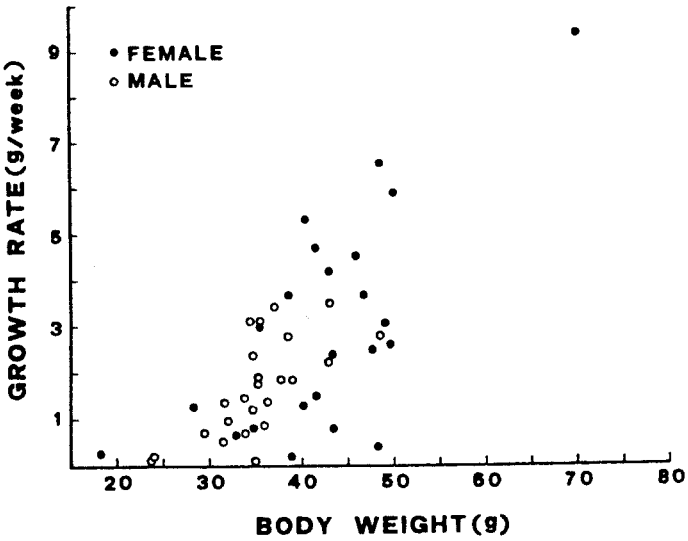

Fig. 16. Size differential growth of *P. monodon* in the wild, as indicated by the tag and recapture data.

About 72% of *M. ensis* prawns from Dapong Bay had empty stomachs, whereas for those from open coastal waters, had only 20% empty (Fig. 13). Based on frequency of occurrence, the relative importance of food items was crustaceans, detritus and sand granules for prawns from Dapong Bay; and detritus, sand granules and crustaceans for prawns from the open coast (Fig. 14). Volumetrically, the order was the same as that described above (Fig. 15).

Tagging and Recapturing of Subadult *P. monodon*

From the combined yearly data of the tagged and recaptured prawns, 64% had moved northward to waters off the mouth of the Kaoping River at depths of 20-60 m, and 36% moved southward to waters between the mouth of Dapong Bay and Fangliao at depths of 10-20 m. The recapture rate of tagged prawns was about 15% for those raised in saltwater ponds of TML and under 5% for those from commercial brackishwater prawn ponds (Table 3). The growth of tagged prawns in the wild ranged from 0.37 to 9.37 g/week for females and 0.06 to 3.52 g/week for males. On the average, the rate was 2.97 g/week for females and 1.67 g/week for males (Fig. 16). Among recaptured females, eight prawns had maturing ovaries.

SUMMARY AND DISCUSSION

By species composition, *Metapenaeopsis barbata*, *Metapenaeus ensis*, *Penaeus semisulcatus*, *P. monodon*, and *Parapenaeopsis cornuta* were the dominant species, comprising 83.97% of the total biomass of specimens collected. Of the five species, *P. monodon*, *P. semisulcatus* and *M. ensis* are commercially important. Hasegawa *et al.* (1975) evaluated the restocking effectiveness of kuruma prawns in Japan and reported that commercial value was the major factor in selecting the appropriate species for release. Accordingly, *P. monodon*, *P. semisulcatus* and *M. ensis* are considered as candidates for release in coastal waters of southwest Taiwan.

Generally, adult penaeid prawns spawn in offshore waters. Eggs hatch and go through a series of planktonic stages. Upon reaching the postlarval stage, they are transported by currents into estuarine waters. In the nutrient-rich estuary, the prawns develop into juveniles and subadults. The prawns then emigrate from the estuary to coastal waters

where they grow into adults (Idyll 1964; Young 1978; Coles and Greenwood 1983; Rothlisberg *et al.* 1985). To supplement the recruits for different stages of the above described life cycle, three sizes of prawn were released. They were: (1) postlarvae, (2) juveniles, and (3) subadults. Release of postlarvae and juveniles has been successful for *P. japonicus* in Japanese waters (Oshima 1984). Release of subadults has been experimented with *P. monodon* (Su and Liao 1986). The strategy for restocking three sizes of prawns in the study area was considered from ecological findings found in the present study.

Restocking of postlarvae

The purpose of restocking postlarvae is to supplement the immigration of postlarvae into the nursery grounds. According to information on the spawning season from the present study and larval development (Liao and Huang 1973), it is estimated that the natural postlarvae of *P. monodon* enter Dapong Bay mainly in June and September. *P. semisulcatus* immigrate mainly in March and April. *M. ensis* enters the estuaries mainly in June and August. After becoming juveniles, these prawns then emigrate to coastal waters. The peaks of emigration occurred from July to December for *P. monodon*, from June to August for *P. semisulcatus*, and from June to October for *M. ensis*. Therefore, the nursery season for *P. monodon* and *M. ensis* was estimated to be from June to December while that of *P. semisulcatus* was from March to August. The nursery season is supposed to be the growing season of postlarvae in the nursery grounds. Therefore, it is better to restock postlarvae during the nursery season.

The rainy season around Dapong Bay occurs in May, June, August and September. The peaks of emigration of *P. monodon*, *P. semisulcatus*, and *M. ensis* from the bay occurred 1-3 months after the rainy season. This fact indicates that rainfall favors the environmantal conditions and food source in Dapong Bay for the growing of prawn postlarvae. Staples (1985) studied the recruitment process of the banana prawn, *P. merguiensis* in the southeastern Gulf of Carpentaria, Australia and recognized the importance of rainfall in determining the strength of recruitment into the offshore fishery. The same conclusion for other prawns from different localities was also noted by Gunter and Edwards (1969), Ruello (1973) and Le Reste (1980). It is, therefore, suggested to restock postlarvae of *P. semisulcatus* from March to June and those of *P. monodon* and *M. ensis* from June to September in Dapong Bay. However, it is necessary to adjust the exact date for restocking to avoid competition for substrate and food between the restocked and the natural groups, and among the different species.

Restocking of juveniles

The purpose of restocking juveniles is to release them into coastal waters to supplement natural recruits in a more direct and effective way. The size of the juveniles for restocking is an important consideration. Larger-size juveniles survive better. However, when juvenile production and transportation are considered, use of larger-size juveniles is not cost effective. Thus, juveniles should be of a size that can acclimatize well in coastal waters as well as escape predators. With this consideration, the proposed minimum size of emigrating prawns from nursery grounds appropriate for restocking are: 20 mm in CL for *P. monodon*, 15 mm in CL for *P. semisulcatus*, and 12 mm in CL for *M. ensis*.

Environmental conditions, including rainfall, moon phase, etc., of coastal waters during the emigration season should be suitable for the new recruits. Therefore, the emigration season is considered as the appropriate season for restocking. For *P. monodon*, this season is from April to December. For *P. semisulcatus*, this season is from July to

December, and for *M. ensis*, from June to December. However, the natural season for juvenile production must also be considered. In this regard, the supply of spawners is the key consideration. The best season for juvenile production for restocking is from August to September for *P. monodon*, April to May for *P. semisulcatus*, and June to July for *M. ensis*. It is therefore proposed that restocking of the juveniles be from July to August for *P. semisulcatus*, August to September for *M. ensis*, and from October to November for *P. monodon*.

The site for restocking is also an important consideration. It is assumed that the main distribution area of a species provides the best environment and a sufficient supply of food for that species. Therefore, it is proposed to restock juveniles into nearshore waters near the main distribution area of the target species. In this regard, it is recommended that *P. monodon* juveniles be restocked in nearshore waters between Linpien and Fangliao, and *P. semisulcatus* and *M. ensis* juveniles be restocked in nearshore waters between Tungkang and Linpien.

The prawns do not emigrate during the daytime as illustrated by the lack of any prawns caught during the daytime in this study. In addition, the prawns prefer to emigrate at the new moon phase. During dark conditions, the emigrating prawn can eacape predators more successfully. Therefore, it is suggested that juveniles be restocked around the new moon phase and during the night.

Food for prawns in the coastal waters was composed mainly of detritus and sand granules. These materials are abundant in the coastal waters (Chinese Naval Hydrographic and Oceanographic Office, 1979). Kuwabara and Akimoto (1986) noted that seidment from these coastal waters was composed mainly of fine sand and very fine sand with a number of silt-clay materials. Values of ignition loss as an indicator of organic matter ranged from 1.15 to 5.38%. Many microorganisms were associated with sand granules. It is anticipated that the released prawns can grow well in the coastal waters.

Restocking of subadults

Due to the accelerated development of *P. monodon* culture in Taiwan, spawners of this species in waters surrounding Taiwan have been seriously overfished. It is estimated that about 500,000 spawners were imported in 1987 (Su, unpublished data). Therefore, the release of pond-reared subadults of this species is expected to increase the stocks of spawners in the coastal waters.

It is supposed that environmental conditions and food in the spawning grounds favors the maturation of subadult prawns. It is, therefore, suggested that subadults be released near spawning grounds, which are located in waters off the estuary of Kaoping River at depths of 30–40 m and between the estuary of Linpien River and Nanshufu at depths of 20–40 m.

The peak hatchery season for *P. monodon* in Taiwan is from March to June. Natural spawners can be caught during the whole year, with most in June and from September to October in the waters along southwest Taiwan. In this regard, it is suggested that subadults be released from October to December with the purpose of cultivating spawners for use of hatcheries the following spring.

It seems that the recapture rate for the prawn from salt water ponds is much better than that from brackish water ponds. This phenomenon reveals that the quality of released prawns influences the recapture rate. Selecting healthy and stout prawns for release is therefore very important for restocking subadults. Based on tagging and recapturing data, the growth potential was 9.37 g/week for female subadults and 3.52 g/week for male subadults in the coastal waters. Liao (1984) reported the best growth of 2.50 g/week for subadults of *P. monodon* in ponds.

Comparing these records, it is clear that the released subadults grow very well. In addition, some recaptured prawns were found in the maturing stage. It is evident that restocking of subadults for cultivating broodstock is quite promising. It must be noted, however, that there must be controls on prawn fishing and water pollution, otherwise these waters cannot be used for sea-ranching.

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從生態學觀點探討如何發展臺灣西南沿岸海域之蝦類栽培漁業

蘇　茂　森

摘　要

發展栽培漁業，以改善沿岸漁業生產，爲臺灣當前漁業發展重點之一。

爲開發臺灣之蝦類栽培漁業技術，臺灣省水產試驗所東港分所以臺灣西南沿岸海域爲模式海域，自 1982 年 7 月至 1986 年 12 月，針對重要經濟蝦類，草蝦、熊蝦、砂蝦，從事一系列有關資源生態之調查研究。

本報告從種類組成、分佈、再生產、加入、食性以及標識放流等方面進行分析研究，依據所得之果，進一步探討草蝦、熊蝦與砂蝦之種苗放流以及草蝦種蝦放流之策略，以作爲爾後實施栽培漁業之結依據。