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Food and Feeding Habits of the White Prawn *Penaeus merguiensis*

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ABSTRACT: Stomach-content analyses revealed that the white prawn *Penaeus merguiensis* de Man, in the Angsa Bank-Klang Strait waters (Straits of Malacca), feed on a variety of food – depending on the locality and availability of food items. In the nursery ground, newly-arrived pelagic postlarvae are carnivores, feeding largely on copepods. Epibenthic postlarvae and juveniles are carnivorous detritivores, consuming mainly organic detritus; they also prey on small animals like foraminiferans, copepods, larval bivalves and brachyuran larvae. In the maturation ground, subadults are detritivorous carnivores, feeding mainly on large crustaceans, like species of *Acetes* and mysids; in lesser amounts, on organic detritus. In the spawning ground, adults are detritivore-carnivores consuming equal amounts organic detritus and a variety of large crustaceans, polychaetes, molluscs and fishes. However, there are indications that the prawn prefer animal food if available. Organic detritus is considered a food supplement; its utilization as a food source becomes important to the maturing prawn when it assumes a benthic existence.

INTRODUCTION

The prawn fishery in Peninsular Malaysia, with a production of 50,000 metric tons, contributed 12 % of the total marine fisheries landed in 1977. It is thus an important marine fishery; in monetary terms it commanded US $ 180 million of the total US $ 405 million valued for all marine fisheries (Annual Fisheries Statistics, 1977). The white prawn *Penaeus merguiensis* de Man is intensively exploited in the coastal waters off the state of Selangor by trawling and bag net operations. The Angsa Bank-Klang Strait waters (Straits of Malacca) form a major part of this coastal fishing ground that produced 20 % of the total prawn catch in Peninsular Malaysia. In view of the potential of prawn culture in Malaysia and of the importance of the prawn fishery, the present investigation on the food and feeding habits of the white prawn was carried out.

There is only one report on the diet of *Penaeus merguiensis* in the Straits of Malacca. Based on a stomach-content study of 35 specimens in the size range of 17–33 mm carapace length, *P. merguiensis* was found to feed mainly on crustaceans and vegetable matters (Hall, 1962). Elsewhere, in the Manila and San Miguel Bays of the Philippines, *P. merguiensis* feeds mainly on phytoplankton and benthonic foraminiferans (Tiews, 1976). In Australia, the prawn is known to consume the remains of small animals and a large amount of unrecognizable material (Dall, 1968).

However, studies on the diet of other penaeid prawns indicate that a wide range of food may be consumed. In the inshore waters off the Madras Coast of India, the morphospecies *Penaeus indicus* feeds mainly on vegetable material and crustaceans, but its diet also include molluscs, foraminiferans, polychaetes, hydroids, trematodes and echinoderm larvae (Gopalakrishnan, 1952). Prawn species of the genera *Penaeus, Metapenaeus, Solenocera, Parapeneopsis* and *Metapenaeopsis* in the Straits of Malacca are known to feed on crustaceans, polychaetes, molluscs, fishes, detritus and algae; *Penaeus* species take in less vegetable matter than *Metapenaeus* species (Hall, 1962). The Australian penaeids are described as omnivorous scavengers or detritus feeders (Dall, 1968).

STUDY AREA AND SPECIMEN CAPTURE

Prawns, at various stages of their life history, were obtained from 3 sites along the Selangor coast from August 1976 to October 1977. They were sampled from their nursery ground in a mangrove-fringed coastal inlet (Sungai Sementa Besar; Lat. 3°5'N, Long. 101°22'E), from their maturation ground off the village

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Kampong Sungai Janggut (Lat. 3°10'N, Long. 101°19'E) and from their spawning ground off the town Sungai Buloh (Lat. 3°15'N, Long 101°19'E) (Fig. 1)

Sungai Sementa Besar, at its midpoint, is as shallow as 1.5 m at the lowest ebb and as deep as 4 m at the highest spring flood. A cast net of 19 mm mesh size was employed to capture prawns, mainly juveniles. Pelagic postlarvae were collected using a 150-µm mesh plankton net fitted with a removable bucket having a 250-µm mesh screen. Epibenthic postlarvae were collected by a nylon marsh net (Pullen et al., 1968) of a mean aperture size of 1 mm.

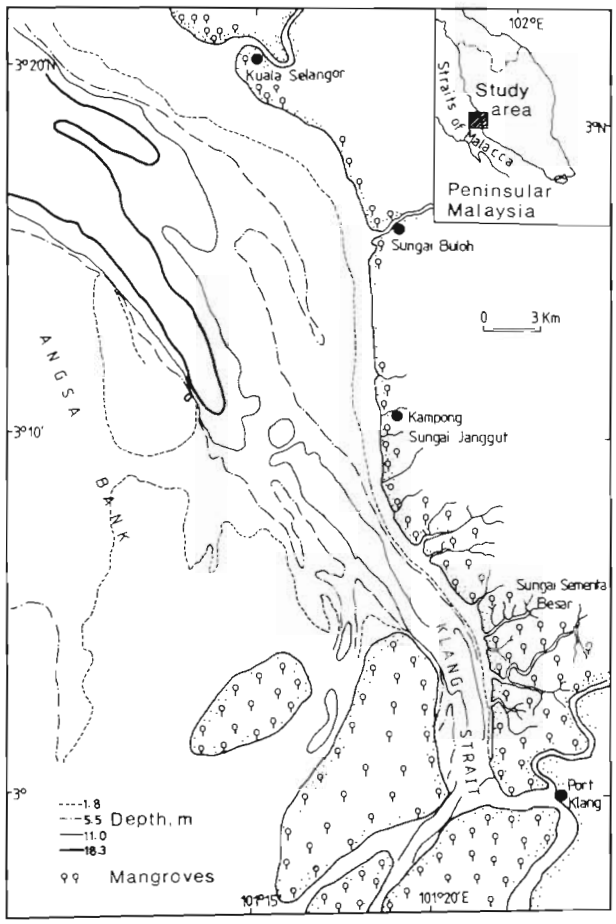

Fig. 1. Study area. Depths adapted from Map of Klang Strait and Approaches. (Based on Admiralty, London 1952)

The maturation ground in the shallow coastal waters off Kampong Sungai Janggut does not exceed 12 m in water depth. Prawns, mainly subadults, were captured by bottom bag nets (gombang) of cod-end mesh size 5 mm. These nets operated 3.2 km offshore at a water depth of 5 m.

The spawning ground, 12 km off-shore, is in excess of 20 m water depth. Prawns, mainly adults, were collected by otter trawl nets having a cod-end mesh size of 25 mm.

The sampling area effectively covered the waters right of Angsa Bank from the northern entrance of the Klang Strait to as far north as Kuala Selangor (Lat. 3°21'N, Long. 101°15'E). Prawns were sampled monthly and preserved in 10 % commercial formaldehyde in sea water.

METHODS

Ingested materials were analysed for their composition and occurrence. Only those in the anterior chamber of the proventriculus ('stomach') were considered. This is because food in the posterior chamber is triturated by the gastric armature (ossicles). The stomachs were arbitrarily classified according to their fullness, as follows: 1 – fully gorged with food; 3/4 – full, but not gorged; 1/2 – half full; 1/4 – containing a small but significant amount of food; 0 – empty, but possibly containing bits of debris.

The entire stomach content was washed onto a rafter cell (50 × 10 × 1 mm), or onto a microscopic slide if the content was small. The rafter cell was able to hold, and allow easy examination of, the food content of even the largest gorged stomach. Minute food items were abundant; their percentage volumetric composition was estimated under a monocular microscope. The percentage volumetric composition of large food items (generally greater than 2 mm diameter) was estimated under a zoom binocular microscope. The entire stomach content was examined without subsampling. The eye-estimation method (McHugh, 1940; Pillay, 1953) applied here made use of an eyepiece grid (10 × 10 squares) to estimate the area occupied by a particular food item. Area estimates are approximately proportional to volume since height differences between fine food items are small. Hence, the contribution of each food item was expressed in percentage volume. For a large food item, its area estimate is 'corrected' according to its height difference with other fine food items.

Food items were identified as far as possible, in most cases to the family level. Percentage occurrences of each food item, expressed in terms of the number of stomachs containing a particular food item based on the total number of stomachs examined throughout the period of study, were obtained for each site. Undigested or non-assimilable rejects in the hindgut were examined qualitatively.

Irrespective of the place of collection, a total of 531 juvenile, subadult and adult prawns were examined and these were from day-catches. Their sizes ranged from 9 mm to 45 mm carapace length (CL). If prawn samples were large, at least 10 specimens from each site and for each month, were examined. A total of 72 postlarval prawns collected in the nursery ground were

analysed. Ten were day-caught and 20 were night-caught pelagic postlarvae with a size range of 2.00–2.85 mm CL. The remainder, 42 individuals, were day-caught epibenthic postlarvae with a size range of 2.25–6.30 mm CL.

RESULTS

Food Classification

The stomachs of most specimens contained at least some materials that formed an amorphous mass. In some cases, such materials could be partially identified, e.g fragments of decomposing vegetation, but more often they were difficult to identify due to their minute size or poor physical state. Organic detritus probably forms a major portion of the amorphous mass, which is also made up of partially broken-up and semi-digested food. For convenience, this amorphous mass of materials is referred to as 'unidentified debris' The term 'plant macrophytes' refers to freshly (green) ingested plant materials. Inorganic particles like sand or silt particles were classed as 'grit'.

It is not known whether prey animals were dead or alive before consumption. The large and more active ones were probably not preyed upon, and were consumed while dead. For example, parts of fish were often present such as scales and bones, and parts of prawns such as antennae, pleopods and eyes. Thus, organic detritus must have been consumed in larger amounts. Fragments of cuticle, if with attached tissues, were assumed to come from a whole animal that had been consumed. If not, they were considered to be exuviae and thus classified as organic detritus under unidentified debris.

Nursery Population

Pelagic postlarvae fed during day and night. The percentage occurrences of empty stomachs in day and night samples were 25 % and 40 % respectively. Filled stomachs ranged from half-full to full (Table 1). There were no differences in the diet composition of day and night-caught postlarvae; calanoid copepods which were present in all stomachs formed the bulk, in most cases a percentage volumetric composition of 100 % Unidentified debris contributed 7 50 % and was present in about 16 % of the stomachs examined.

Most of the epibenthic early-postlarvae, in the size range 2.25–3.15 mm CL and caught during the day, had empty stomachs. Of 28 individuals examined, only 2 had filled stomachs which were 1/4-filled with unidentified debris. Epibenthic late-postlarvae, in the size range 3.2–6.3 mm CL mm, had mainly filled

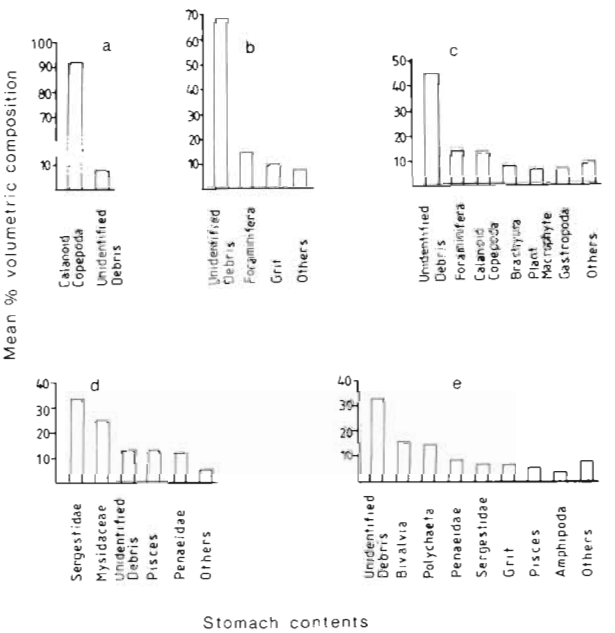

Fig. 2. *Penaeus merguiensis*. Relative importance of major stomach contents. (a) Nursery population, pelagic postlarvae; (b) nursery population, epibenthic postlarvae; (c) nursery population, juveniles; (d) shallow coastal population, late juveniles, subadults and adults; (e) deep offshore population, subadults and adults

Table 1 *Penaeus merguiensis*. Frequency of stomachs encountered in 5 different states of fullness

Area	Stomach fullness					Total examined
	0	1/4	1/2	3/4	1	
Nursery ground						
Pelagic postlarvae	9	–	3	18	–	30
Epibenthic postlarvae of						
2.25–3.15 mm CL	26	2	–	–	–	28
3.20–6.30 mm CL	1	–	6	7	–	14
Juveniles	8	8	43	30	93	182
Maturation ground						
Subadults (including late juveniles and adult males)	12	20	60	28	69	189
Spawning ground						
Adults (including subadults)	26	32	52	22	28	160

stomachs (1/2 – 3/4-filled); only 1 of 14 individuals had an empty stomach. They fed mainly on unidentified debris which was found in all stomachs (Fig. 2) The percentage volumetric composition of unidentified debris ranged from 20–100 %. Foraminifera (mainly *Gyroidina* sp.: Rhotallidae) were present in 54 % of the stomachs examined, with one stomach containing as much as 48 % of the total volume of stomach content. Grit occurred in variable amounts in 60 % of the stomachs examined, ranging from 10–22 % of the volume. Other stomach contents, constituting 7.4 % of the volume, included calanoid and harpacticoid copepods, larval bivalves and diatoms.

The average percentage volumetric composition of the various stomach contents of juvenile prawns in the size range 9–21 mm CL is shown in Fig. 2. Stomach fullness ranged from empty to gorged. Unidentified debris and foraminiferans (Rhotaliidae) contributed a percentage volume of 45 % and 15 % respectively These items were observed to occur exclusively in some stomachs. Unidentified debris occurred in 85 % of the stomachs examined (Table 2). It was consumed in all months, being the dominant item in almost every month – except August and December in 1976 and January, March and September in 1977 (Fig. 3). During these months foraminiferans were mainly consumed and a diet exclusively composed of foraminiferans was not uncommon.

Of the small crustaceans, mainly calanoid copepods (13 %) and brachyuran megalopae (7 %) were consumed by juvenile prawns. Calanoid copepods were largely consumed in December (1976), January, June

Table 2. *Penaeus merguiensis*. Stomach-content analysis (empty stomachs not considered)

Stomach content	Nursery population No. examined: 174		Shallow coastal population No. examined: 177		Deep off-shore population No. examined: 135	
	Occurrence	%	Occurrence	%	Occurrence	%
Unidentified Debris	148	85	61	34.5	93	68.9
Protozoa						
Foraminifera	85	48.9	1	0.6	5	3.7
Radiolaria					9	6.7
Tintinnida	9	5.2				
Crustacea						
Calanoid copepoda	102	58.6	24	13.6	8	5.6
Harpacticoid copepoda	43	24.7	3	1.7		
Ostracoda	2	1.1				
Hyperiid amphipod			5	2.8	12	8.9
Gammarid amphipod			1	0.6	16	11.8
Isopoda			1	0.6	1	0.7
Cirripedia	20	11.5			2	1.5
Stomatopoda					1	0.7
Mysidacea	2	1.1	72	40.7		
Penaeidae	8	4.6	41	23.2	35	25.9
Sergestidae			86	48.6	18	13.3
Palaemonidae	1	0.6				
Alpheidae					2	1.5
Anomura			2	1.1		
Brachyura	48	27.5	9	5.1	17	12.6
Chelicerata						
Acarina	1	0.6				
Pycnogonida					1	0.7
Insecta						
Formicidae	15	8.6				
Mollusca						
Gastropoda	35	20.1	1	0.6	8	5.9
Bivalvia	5	2.9	1	0.6	31	23.0
Cephalopoda			2	1.1	2	1.5
Annelida						
Polychaeta	15	8.6	6	3.4	64	47.4
Nematoda	36	20.7	1	0.6	3	2.2
Echinodermata					1	0.7
Pisces	34	19.5	62	35.0	25	18.5
Plant Macrophytes	112	64.4	19	10.7	38	28.1
Algae & Diatoms	20	11.5	2	1.1	5	3.7
Grit	14	8.0	2	1.1	57	42.2

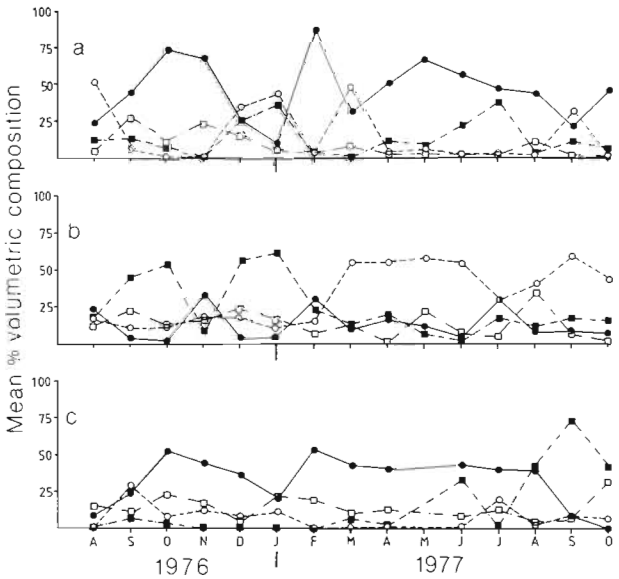

Fig. 3. *Penaeus merguiensis*. Monthly variations in composition of major stomach contents. (a) Nursery population: ● unidentified debris, ○ Foraminifera, ■ calanoid Copepoda, □ Brachyura. (b) Shallow coastal population: ● unidentified debris, ○ Acetes, ■ Mysidaceae, □ Pisces. (c) Deep off-shore population: ● Unidentified debris, ○ Penaeidae, ■ Bivalvia, □ Polychaeta

and July (1977), and brachyuran larvae in the period September–December. Faunistic elements consumed in small amounts included gastropods, bivalves, ostracods, penaeids, carideans, cypris larvae, mysids, tintinnids, polychaetes, nematodes, fishes, ants and mites.

Although fresh plant materials constituted a percentage volume of only 6 % of the diet, their combined percentage occurrence in stomachs was about 64 %. Such plant materials included parts and pieces of macrophyte vegetation (mainly mangroves), filamentous blue-green algae (e.g. *Trichodesmium* and *Microcoleus* spp.) and diatoms (e.g. *Coscinodiscus, Cyclotella, Pleurosigma* and *Gyrosigma* spp.). Plant macrophytes were present in all stomachs every month, but only in small amounts.

Shallow Coastal Population

The maturing population, mainly subadults including late-juveniles and adults (size range 15.5–33.5 mm CL), consumed largely sergestids (*Acetes* sp.) and mysids which constituted a percentage volume of 33 % and 24 % of the diet respectively. They were consumed throughout the year, species of *Acetes* being largely taken during the period March–October and mysids during the period September–January (Fig. 3). During these periods, the prawns may exclusively consume these food organisms. *Acetes* occurred in about 48 % and mysids in about 40 % of the stomachs examined (Table 2). Stomach fullness ranged from empty to gorged.

Of lesser importance in the eiet of maturing prawns were unidentified debris, fishes and penaeid prawns, each contributing some 12 % of the volume. They were generally consumed throughout the year. Other items included foraminiferans, brachyuran magalopae, copepods, isopods, cephalopods, polychaetes, nematodes, macrophytes, algae and grit which collectively totalled 5 % of the volume. None of these items dominated in any stomach for any month.

Deep Off-Shore Population

Prawns from the deep-offshore population, mainly adults (and subadults) in the size range 23–45 mm CL, had a percentage volume of 32.5 % of unidentified debris in their stomachs, which were mostly half-filled. Considerable amounts of polychaetes and bivalves (percentage volumes of 14 % and 15 % respectively) had been consumed, the former throughout the year, the latter usually from August to November Young bivalves were consumed; in the months when they were abundant in the diet, they were present exclusively in some stomachs. Ingested bivalves and gastropods were always in a crushed state. Tentacles of small cuttlefish were found in two adult stomachs. One prawn (34 mm CL) consumed a single tentacle measuring 40 mm in length and 4 mm in maximum diameter!

Large crustaceans, like penaeids and sergestids (*Acetes* and *Leucifer* spp.) contributed a percentage volume of about 14 % of the diet. Small crustaceans such as amphipods contributed a percentage volume of 4 % (July–September). Tubiculous gammarids were more represented than hyperiids. In one prawn, amphipods contributed a percentage volume of 47 % of its diet. Less common crustaceans included brechyuran megalopae, alpheids, isopods, cirripeds and stomatopods.

Fish formed a percentage volume of 5 % of the prawn's diet. Grit (6 %) and plant macrophytes (negligible) were invariably present in almost all stomachs throughout the year. Other items were radiolarians, echinoderm larvae and pycnogonids.

Hindgut Contents

Cuticular exoskeletons of crustaceans, tests of foraminiferans, shells of molluscs, fish bones, setae of polychaetes and plant fragments were observed in the hindgut. Calcareous shells or tests were always in a

finely-ground state. Apparently, these materials were not adequately triturated or digested by the prawn.

DISCUSSION

The spatial and seasonal variation in the type and quantity of food consumed suggest that the diet of *Penaeus merguiensis* is related to food availability. Within this food availability, there are indications of food selection. Since diatoms and blue-green algae are abundant in the substrata (Chong, 1977) but seldom selected, a preference for animal food is apparent. More than 28 taxa of prey animals were observed. Although the prawn shows versatility in handling food of varying sizes, it is unlikely that small individuals can prey on large and active animals. In the nursery ground, foraminiferans, copepods and brachyuran megalopac were commonly selected by juveniles but not the larger sergestids, mysids and juvenile fishes which were also abundant. Thus, food selection is determined by food palatibility, prey size and activity; the larger active preys can only be preyed upon by larger prawns.

It is unlikely that organic detritus is a limiting food resource in the benthos of the nursery or maturation ground. In the nursery ground, allochthonous mangrove detritus is available throughout the year. Mangrove detritus is also exported to the adjacent maturation ground by ebb tides. However, foraminiferans and other small animals occasionally form the bulk of the food ingested by juvenile prawns while subadult prawns feed mainly on species of *Acetes*, mysids and fishes. The insignificant amount of organic detritus in the gut of these prawns is not due to its limiting supply but rather to its exclusion in the diet when there is an abundance of animal food.

However, organic detritus (as unidentified debris) appear quite regularly in the diet of the prawn (Table 2.) The utilization of organic detritus as a food source appears to be important to the maturing prawn when it assumes a benthic existence. Organic detritus probably supplements when other preferred food items are scarce. It is not known if it is directly utilized; however, decomposed plant fragments were observed in the hindgut. Particulate detritus is known to serve as a substrate for micro-organisms like bacteria, fungi and protozoans. These micro-organisms are probably more important as food than the substrate (Newell, 1965; Darnell, 1967; Sushenya, 1968; Fenchel, 1970). The latter provides food to the former which, in turn, serves as food to the prawns. In the proventriculus of *Metapenaeus bennettae*, which feeds on muddy estuarine sediments, bacteria compose 20–35 % of the organic carbon (Moriarty, 1976).

Preference for animal food could be related to taste preference and to the relative ease the food can be triturated by the gastric armature, processed by the 'filter-press' and digested by the hepatopancreas. It could also be related to the prawn's high protein requirement. Optimum protein levels required for the prawn were estimated in the range of 34–42 % for diets of energy content 2.9–4.4 Kcal g^{-1} (Sedgwick, 1979). Further, proteins are known to be easily assimilated by some prawn species (Wickins, 1976), and feeding efficiency and growth are increased when the protein content is raised to an optimum level (Lee, 1971; Deshimaru and Shigueno, 1972).

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