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The Feeding Ecology of the Blue Swimming Crab, *Portunus pelagicus* (Linnaeus, 1758), at Kung Krabaen Bay, Chanthaburi Province, Thailand

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Abstrak: Diet semula jadi ketam renjong, *Portunus pelagicus*, telah dikaji dari Oktober 2008 hingga Oktober 2009 menggunakan penyampelan tangan dan 'crab gill net'. Keputusan telah menunjukkan bahawa pemangsa utama dalam kandungan perut *P. pelagicus* ialah ikan teleos (29.61%), bahan organik (20.69%), krustasia (18.3%) dan moluska bercangkerang (11.46%). Perbezaan ketara telah dijumpai dalam komposisi diet antara ketam juvenil dan matang, antara ketam di dalam dan di luar kawasan teluk dan antara musim. Secara kontranya, perbezaan ketara tidak dijumpai antara ketam jantan dan betina.

Keywords: Ekologi Pemakanan, Ketam Renjong, *P. pelagicus*, Anjakan Ontogenetik, Kung Krabaen Bay

Abstract: The natural diet of blue swimming crabs, *Portunus pelagicus*, was investigated from October 2008 to October 2009 using hand sampling and a crab gill net. The results showed that the major prey items in the stomach contents of *P. pelagicus* were teleost fish (29.61%), organic matter (20.69%), crustaceans (18.3%) and shelled molluscs (11.46%). Significant differences were found in diet composition between juvenile and mature crabs, between crabs inside and outside the bay and among seasons. In contrast, significant differences were not found between male and female crabs.

Keywords: Feeding Ecology, Blue Swimming Crabs, *P. pelagicus*, Ontogenetic Shift, Kung Krabaen Bay

INTRODUCTION

The blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) has a broad geographical distribution throughout the Indo-Pacific region (Kailola *et al*. 1993). The species is usually found in large numbers in shallow bays with sandy bottoms (Williams 1981). This crab is a very important commercial species in many countries, such as Australia, Japan, India and the Southeast Asian countries, particularly Thailand. These crabs are distributed throughout the coastal areas in the Andaman Sea and the Gulf of Thailand in a total of 21 provinces of Thailand. During the past decade, the production of *P. pelagicus* in Kung Krabaen Bay has decreased markedly (Tantichaiwanit *et al*. 2010; Raungprataungsuk 2009; Bhatrasataponkul *et al.* 2008; Kunsook 2006). A comparison between the production of *P. pelagicus* in 2002 (120 tonnes) and the

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production in 2012 (50 tonnes) clearly demonstrates the 58.33% decrease in production (Kunsook 2012). Additionally, the size of the crabs has decreased markedly. However, *P. pelagicus* fishing still plays an important role, in ecological and socio-economic terms, in Kung Krabaen Bay (Fig. 1). It is an important source of local income and job opportunities for villagers. It also plays an important role in terms of ecology due to its relationship to various trophic levels in food webs**.**

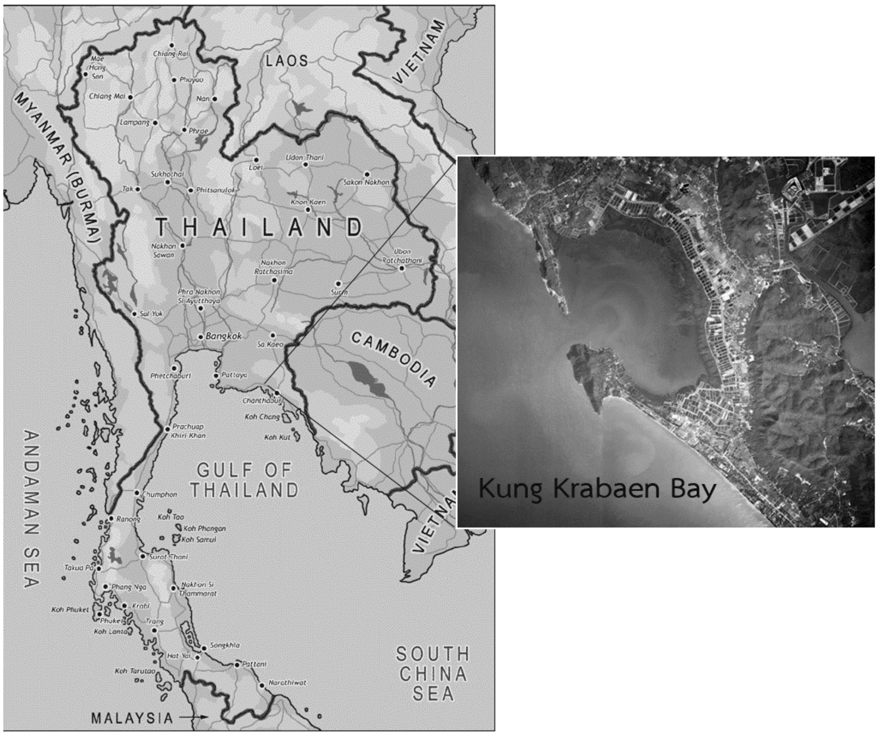


Figure 1: Kung Krabaen Bay, Chanthaburi Province, Thailand.

The natural diet of *P. pelagicus* has been extensively studied by examining the stomach contents using two measures: frequency of occurrence and per cent occurrence (Edgar 1990; Williams 1981, 1982; Hyslop 1980; Patel *et al*. 1979). The results of these studies indicate that *P. pelagicus* is primarily carnivorous, feeding on a wide variety of benthic animals. Smaller quantities of marine plants and seagrass are also consumed (Wu & Shin 1998). *P. pelagicus* is considered to be an opportunistic predator. Its diet depends on the availability of food items (Williams 1982). Williams also found that the diet composition of *P. pelagicus* changes only slightly with the size of the crab, in contrast to other brachyurans, whose prey species change with increasing crab size. This finding is consistent with the results of Edgar (1990), who found size-related changes in the diets of crabs. These ontogenetic niche shifts are influenced by the differences between the habitats used by small and larger crabs. During the planktonic phase, the larvae are plankton feeders, feeding on phytoplankton and zooplankton, e.g., *Chaetoceros* and rotifers (Josileen & Menon 2004). The natural diet of juveniles and adult crabs in Kung Krabaen Bay has been studied by Kunsook (2006) using a collapsible crab trap. The results of that study show that the principal food items of immature males were molluscs, fish and crustaceans. The principal food items of mature males were fish, crustaceans and molluscs. Immature females fed primarily on fish, molluscs and crustaceans, whereas mature females fed on fish, crustaceans and squid. However, that study was conducted only inside the bay. The adult crabs outside the bay were not investigated. In addition to the bias from the sample sites, the estimate of the fish component of the diet was excessively high because the collapsible crab trap also trapped fish. Hand sampling and a crab gill net were used in the current study to avoid biased samples of prey. A study of the dietary composition of *P. pelagicus* in Australia showed that juvenile crabs consumed a large quantity of crustaceans and bivalve molluscs, whereas adult crabs fed on polychaetes and crustaceans (de Lestang *et al*. 2003). The natural diet of juvenile and adult *P. pelagicus* has also been investigated along the coast of Mandapam, Tamil Nadu, India. The results of that study showed that juvenile crabs [<80 mm carapace width (CW)] fed primarily on debris (41.4%), followed by crustaceans (27.7%) and miscellaneous items (19.2%). In smaller adults (100–140 mm), crustaceans were the principal food item, whereas larger adults (141–180 mm) fed on fish and miscellaneous items (Josileen 2011).

A study of the natural diet of *P. pelagicus* larvae and juveniles in Kung Krabaen Bay strongly indicated the importance of seagrass beds as the nursery habitat and food source for crab larvae and juveniles. The megalops larvae settled in certain habitats that provided protection (Raungprataungsuk 2009). Migration by the crabs was performed not only for reproduction but also to find suitable food sources. Food availability for the crabs depended on seasonal variation and environmental changes, such as salinity and temperature changes. Ontogenetic niche shifts also affect the migration of brachyuran decapods (Pittman & McAlpine 2003). Currently, *P. pelagicus* are overharvested, and the population of this crab in the natural habitat is insufficient to meet consumer demands. The sustainable management of this crab species, e.g., based on culturing and restocking the juvenile crabs, has been proposed in previous studies (Tantichaiwanit *et al*. 2010; Raungprataungsuk 2009; Kunsook 2006). Dietary studies are important for identifying the food consumed by the crab. This knowledge is also useful to facilitate the successful culture of the species (Josileen 2011). This study aimed to investigate the composition of the natural diet of *P. pelagicus* inside and outside Kung Krabaen Bay and analysed the factors affecting the feeding ecology of the crab, such as sex, size, season and the use of habitat inside and outside the bay. The results of this study will be useful for improving and developing cultural techniques for *P. pelagicus* in Kung Krabaen Bay.

MATERIALS AND METHODS

Study Area

Kung Krabaen Bay is one of the important fishing grounds for *P. pelagicus* in Thailand. It is located in the eastern Gulf of Thailand between latitude 12°34'–12°12'N and longitude 101°53'–101°55'E. The climate of the Kung Krabaen Bay ecosystem is seasonal. The dry season typically extends from November to April, and the wet season extends from May to October. This climate is influenced by the two monsoons, the northeast monsoon and the southwest monsoon. This area has many diverse habitat types, including mangrove forests, coral reefs and seagrass beds. Therefore, this bay supports abundant economically important marine animals, particularly *P. pelagicus*. Kung Krabaen Bay is currently one of the areas included in many planned Thailand Fishery Improvement Projects (FIPs), particularly crab management projects (National Fisheries Institute Crab Council 2013).

Data Collection

The natural diet of crabs was studied from October 2008 to October 2009 by analysing stomach contents. The results of these analyses for inshore and offshore crabs were compared. *P. pelagicus* was collected by hand at inshore locations during the lowest tides at 12 sampling sites. The crabs were caught by grasping the carapace near the swimming leg. *P. pelagicus* was also collected offshore with a crab gill net with a mesh size of 10 cm and a length of 500 m. The crabs were preserved immediately in 10% buffered formalin. The foregut of each crab was removed, fixed in formalin and stored in 70% ethanol for dietary analysis. The CW and sex were recorded for each individual. The foregut contents were examined under a stereomicroscope. Prey items were sorted into broad taxonomic groupings. Juvenile crabs and adult crabs were classified according to CW. Juvenile males were considered to have a CW less than 7 cm, and adult males were considered to have a CW of 7 cm or more; juvenile females were considered to have a CW less than 8 cm, and adult females were considered to have a CW of 8 cm or more (Kunsook 2006).

Data Analysis

Dietary composition was analysed with the percentage point method (Williams 1981), the frequency-of-occurrence method (Wear & Haddon 1987; William 1981) and the Index of Relative Importance (IRI) (Hyslop 1980).

For the percentage point method, after the stomach was removed it was scored from 1–5, according to the degree of fullness, i.e., approximately 100%, 75%, 50%, 25% and 0%. Food categories were given a value ranging from 0–100 according to the percentage of the stomach contents of a given individual represented by that category. The number of points that each category received was weighted according to the actual fullness of the stomach in which it was found. For example, in a stomach that was half full and contained 25% molluscs and 75% crustaceans, the molluscs received a score of 12.5 points, the crustaceans a score of 37.5 points.

$$P = (F/A) \times 100\%,$$

where
P = percentage points for each prey category
F = total points for each prey category
A = total points for all prey categories.

The frequency-of-occurrence method was applied by dividing the number of stomachs that contained a given food category by the total number of stomachs observed.

$$PO = (O/N) \times 100\%,$$

where
PO = percentage occurrence of prey item
O = number of stomachs that contained a given prey type
N = number of crabs in the sample, excluding crabs with empty stomach contents.

The IRI (Hyslop 1980) was calculated for all of the prey items using the formula:

$$IRI = (C_N + C_P) + F,$$

where
C_N = percentage based on number of prey
C_P = percentage points
F = percentage of occurrence.

The food items were classified into the following nine categories: crustaceans, fish, molluscs, squid, sponges, seagrass, algae, organic matter or unidentified and sand or debris. These food items were identified based on observations of body parts such as the carapace, appendage, fin, scales, and bones under a stereomicroscope (Josileen 2011). A one-way analysis of variance (ANOVA) was used to test the relationship between the dietary composition and factors such as sex, size, habitat type and seasonality. A significance level of $p<0.05$ was used for the statistical analyses (de Lestang *et al*. 2000).

RESULTS

Food Items

The stomach contents of 262 *P. pelagicus* were analysed. In all, 140 male crabs with CWs ranging between 4.49–14.26 cm and 122 female crabs with CWs ranging between 4.07–16.73 cm were examined. The frequency-of-occurrence method showed that the major prey items in the stomach contents of *P. pelagicus* were teleost fish (29.61%), organic matter (20.69%), crustaceans (18.3%) and shelled molluscs (11.46%), respectively (Fig. 2). The teleost fish in the stomachs could not be identified to species due to the crushing and grinding of the food items that occurred during the feeding behaviour of the crabs.

The percentage point method showed trends similar to those found with the frequency-of-occurrence method. Teleost fish were the principal food item in the stomachs (29.62%). The percentages of crustaceans, organic matter and molluscs were the next highest (21.2%, 18.36% and 18.21%, respectively). Sand (4.22%), squid (2.93%), algae (2.61%), sponges (2.29%) and seagrass (0.56%) were found in smaller quantities (Fig. 3).

The IRI for the food items confirmed the identity of the principal prey items. The IRI values ranged from 0.07% to 41.18%. The highest percentage IRI was found for teleost fish (41.18%), whereas the lowest (0.07%) was found for seagrass (Table 1).

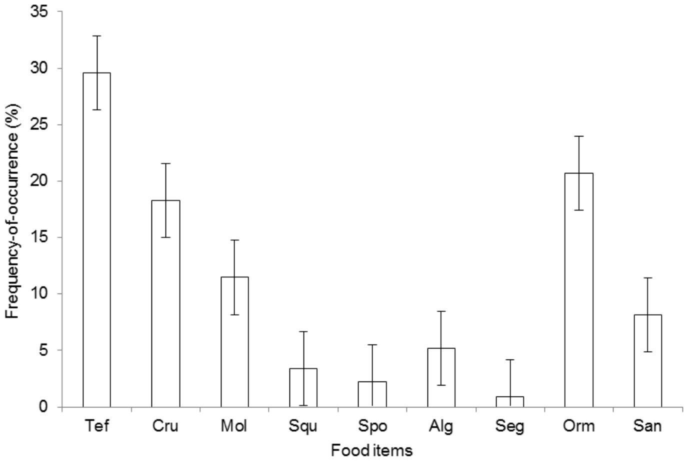


Figure 2: Food items of *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province calculated by frequency-of-occurrence method.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

Ontogenetic Niche Shift

Significant differences in diet composition were found between juvenile and mature crabs (p<0.05). The principal food items of the juvenile male crabs were teleost fish (31.65%), crustaceans (18.99%) and molluscs (17.72%), and the principal food items of the adult male crabs were teleost fish (30.13%), organic matter (22.59%) and crustaceans (19.25%) (Fig. 4). Sponges were absent from the stomachs of the juvenile male crabs but were found in the adult male crabs. Moreover, algae and seagrass were found in the stomachs of the juveniles (Figs. 4 and 5). This study confirmed the importance of seagrass beds as feeding grounds for juveniles, consistent with the movement pattern of the crabs within the bay. The food items in the juvenile and adult female *P. pelagicus* stomachs followed trends similar to those reported for the male crabs. The principal food items of the juvenile female crabs were teleost fish (33.33%), crustaceans (18.75%) and molluscs (14.58%), and the principal food items of the adult female crabs were organic matter (30.93%), teleost fish (29.66%) and crustaceans (14.41%) (Figs. 6 and 7).

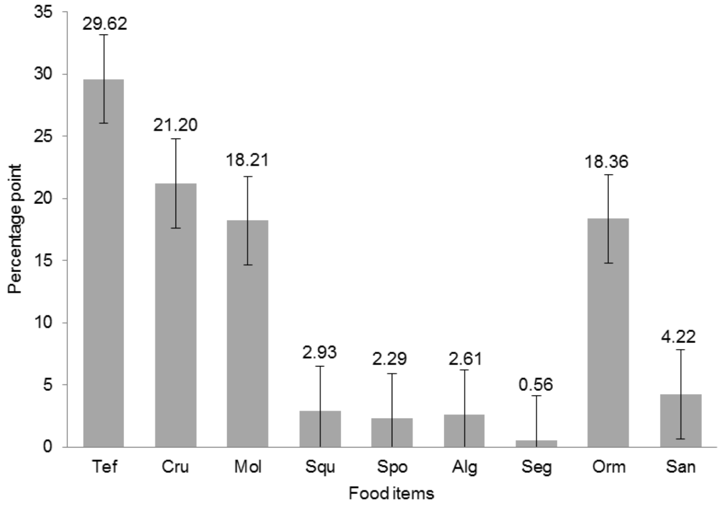


Figure 3: Food items of *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province calculated by percentage point method.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

Table 1: Index of relative importance (IRI) and percentage IRI of food items of *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province based on stomach contents.

Food items	Frequency-of-occurrence (FO)	% FO	Point (PT)	% PT	Numerical (N)	% N	IRI	% IRI
Teleost fish	199	29.61	1010	29.62	322	20.60	1487.19	41.18
Crustaceans	123	18.30	723	21.20	473	30.26	942.03	26.09
Molluscs	77	11.46	621	18.21	192	12.28	349.43	9.68
Squid	23	3.42	100	2.93	89	5.69	29.52	0.82
Sponges	15	2.23	78	2.29	35	2.24	10.11	0.28
Algae	35	5.21	89	2.61	97	6.21	45.93	1.27
Seagrass	6	0.89	19	0.56	38	2.43	2.67	0.07
Organic matter	139	20.68	626	18.36	205	13.12	651.03	18.03
Sand	55	8.18	144	4.22	112	7.17	93.18	2.58
Total	672		3410		1563		3611.09	

Significant differences in food items were found between crabs inside and outside the bay ($p<0.05$). The principal food items of crabs inside the bay were teleost fish, crustaceans, molluscs and organic matter, whereas the principal food items of crabs outside the bay were organic matter, teleost fish, sand and crustaceans. The less common food items of crabs inside the bay were molluscs (13.76%), organic matter (13.76%), sand (7.57%), algae (5.73%), squid (5.28%) and seagrass (1.15%). Sponges were absent from the crab stomach contents inside the bay but were found in crabs outside the bay; squid and seagrass were found only in the crab stomach contents inside the bay. Moreover, a high percentage of organic matter was found in the stomach contents of crabs outside the bay (Fig. 8).

Male and female crabs shared the principal food items, including teleost fish, organic matter and crustaceans, in similar proportions, with slightly higher frequencies of most food types in the female crabs except for organic matter and sponges (Fig. 9). No statistically significant differences were detected between the diets of male and female crabs.

However, the diet composition differed significantly between crabs collected in the wet and dry seasons (p<0.05). In the dry season, teleost fish (26.26%), organic matter (24.67%) and crustaceans (15.38%) were the most frequently consumed items, whereas in the wet season, teleost fish (39.86%), crustaceans (19.23%) and organic matter (16.43%) were the principal food items. Moreover, certain food items, e.g., sponges and seagrass, were found in the dry season but were absent in the wet season (Fig. 10).

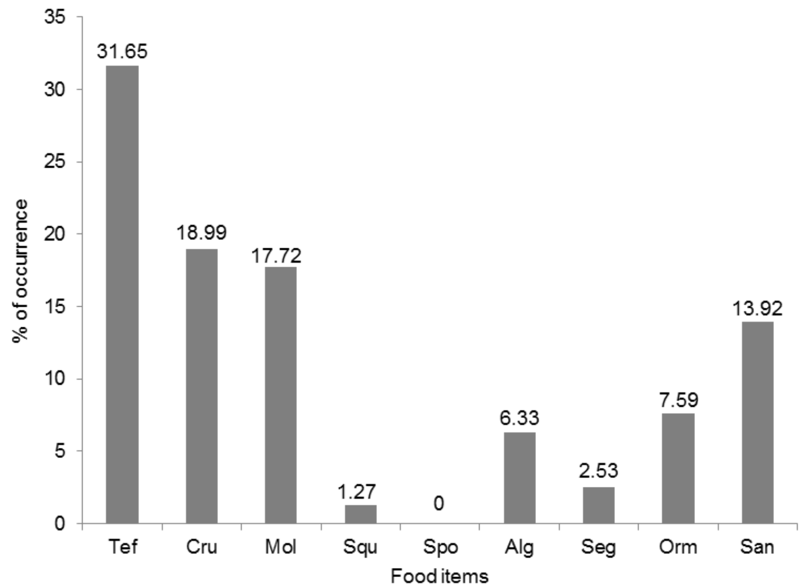


Figure 4: Percent occurrence of food items of immature male *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.

Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

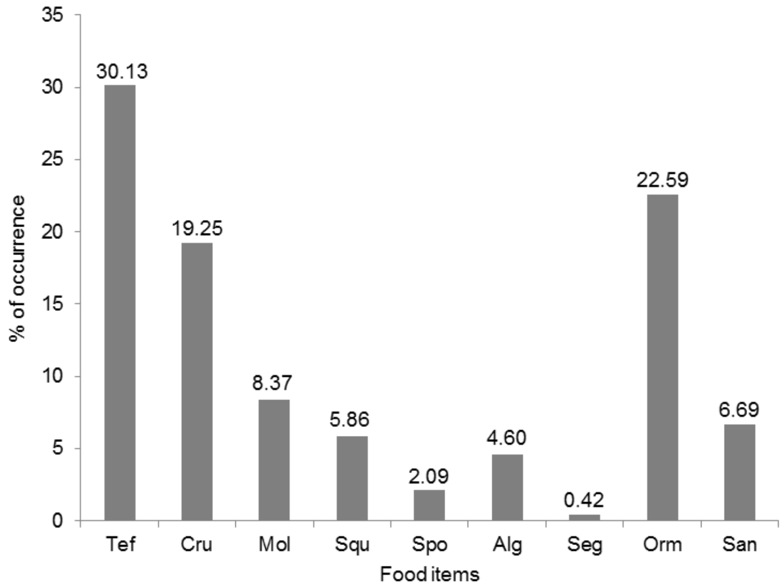


Figure 5: Percent occurrence of food items of mature male *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

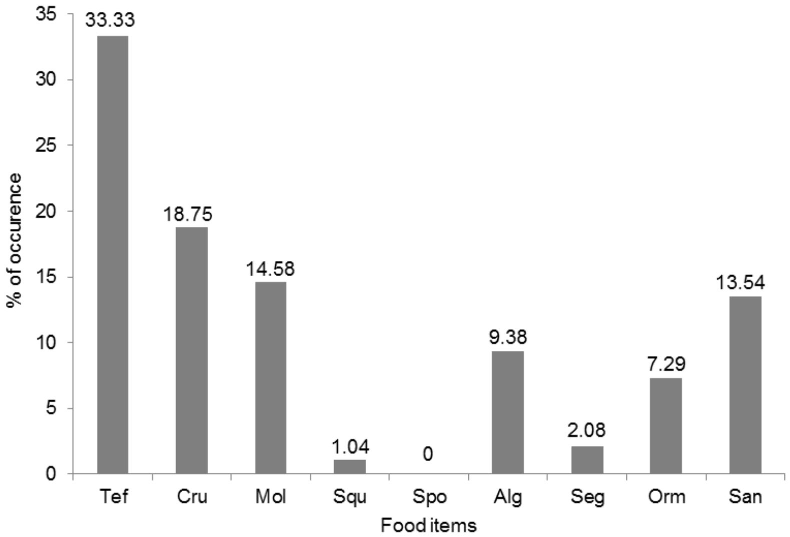


Figure 6: Percent occurrence of food items of immature female *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

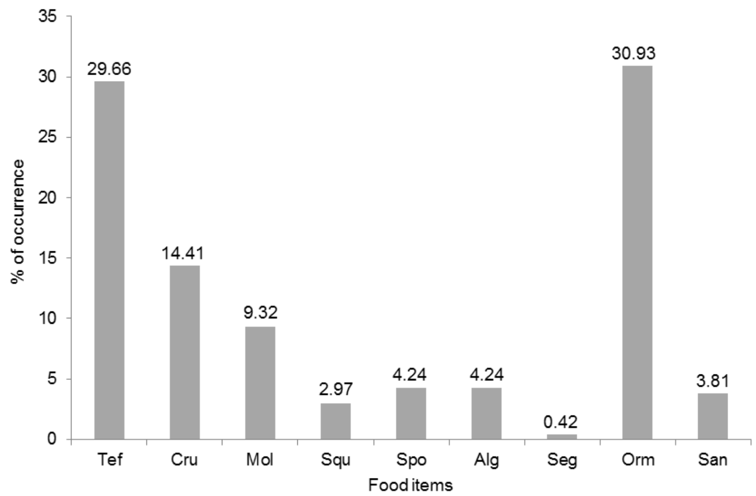


Figure 7: Percent occurrence of food items of mature female *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

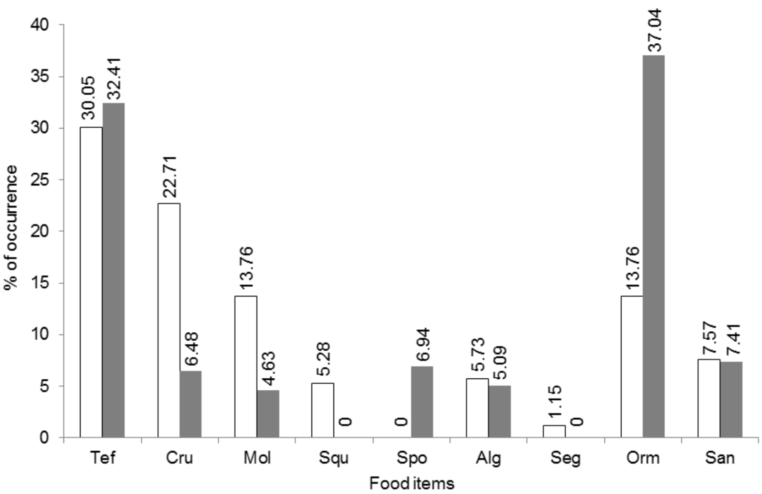


Figure 8: Percent occurrence of food items of *P. pelagicus* inside and outside (darker bar) Kung Krabaen Bay, Chanthaburi Province.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

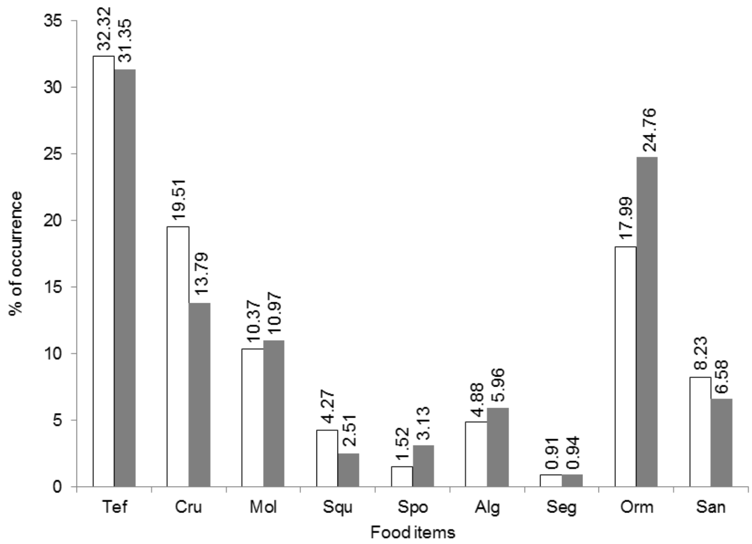


Figure 9: Percent occurrence of food items of male and female (darker bar) *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

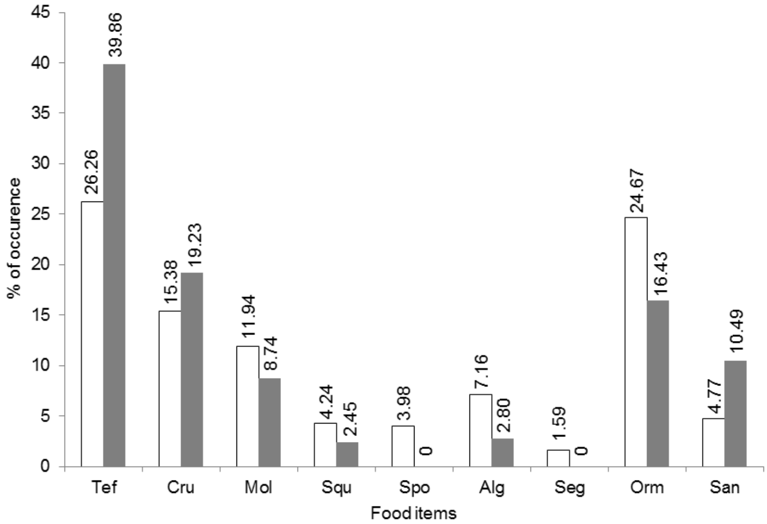


Figure 10: Percent occurrence of food items of *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province in dry and wet (darker bar) seasons.
Note: Tef, teleost fish; Cru, crustaceans; Mol, molluscs; Squ, squid; Spo, sponge; Alg, algae; Seg, seagrass; Orm, organic matter; San, sand

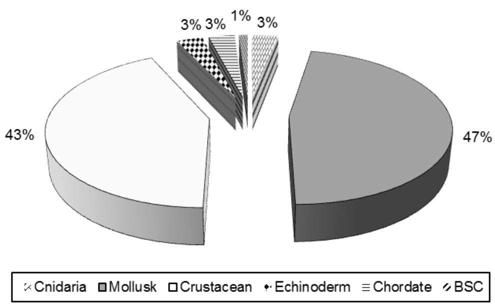
DISCUSSION

Comparisons of Diets in Kung Krabaen Bay and in Other Coastal Marine Waters

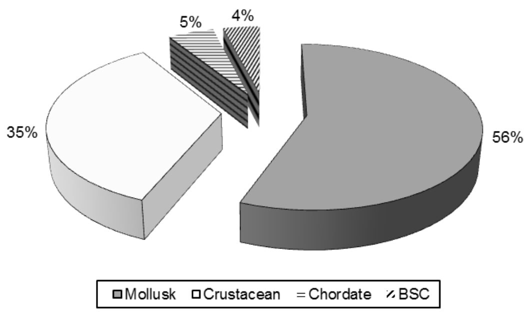
P. pelagicus in Kung Krabaen Bay is predominantly a carnivore and scavenger, primarily feeding on teleost fish and on invertebrate prey including molluscs and crustaceans. In contrast to previous reports on the natural diet of *P. pelagicus* elsewhere (Chande & Mgaya 2004; Wu & Shin 1998; Edgar 1990; Wassenberg & Hill 1987; Williams 1982, 1981; Patel *et al.* 1979), the current study found that *P. pelagicus* fed primarily on sessile or slow-moving invertebrates. Therefore, the dominance of teleosts in the diet of *P. pelagicus* in Kung Krabaen Bay may reflect scavenging activity by the crab. The species of crustacean that occurred in the stomach contents of the crabs were the crossed-marked swimming crab *Charybdis feriatus*, the spiny rock crab *Thalamita crenata* and the moon crab *Matuta banksii*. *P. pelagicus* were also included in the diet as a result of cannibalism. This result is in agreement with the report by Kunsook (2006) that portunid crabs were dominant prey items and were abundant in the area. Indeed, feeding by the crabs was closely correlated with the distribution and density of prey. Algae and seagrass were of minor importance in the diet of *P. pelagicus* even though the seagrass species *Enhalus acoroides* and *Halodule pinifolia* were prevalent in Kung Krabaen Bay. This finding suggests that plant materials may be ingested accidentally as prey items are gleaned from among algae and seagrass (Williams 1981). Moreover, this study indicated that most juvenile *P. pelagicus* inhabit this area. Several studies have shown that seagrass beds are frequently used as nursery habitat by juvenile marine animals because they provide a refuge from predators and a greater abundance of food (Jackson *et al*. 2001). Recently, the food and feeding habits of *P. pelagicus* were studied on the coast of Mandapam, Tamil Nadu, India. The results of that study showed that crustaceans, molluscs, fish, unidentified items and debris are the principal items in the diet and that crustaceans are the major food item of this species (Josileen 2011).

Feeding Patterns of *P. pelagicus* in Kung Krabaen Bay

The diet of *P. pelagicus* did not vary with the sex of the crab. Williams (1982) noted that males and female crabs ate similar types of food and ate the same quantities of food. Edgar (1990) found no differences between the food types of male and female *P. pelagicus* in Western Australia, but a larger quantity of food was found in the stomachs of the female crabs than in those of the male crabs, suggesting that the female crabs need more energy for ovogenesis. Similarly, Cannicci *et al.* (1996) found that the females of *T. crenata*, a species of portunid, consumed more food than the male crabs. Chande and Mgaya (2004) reported no significant difference in food types between sexes, sizes or seasons. However, significant differences were recorded among the various food items. Josileen (2011) found no significant differences between the sexes but significant differences among the size groups of the crabs. The results of that study are related to our results because they found differences between the feeding patterns of juvenile and mature crabs. These findings reflect the ontogenetic changes occurring in the species. Juvenile crabs pass through frequent moulting stages during growth, and calcium is required for shell formation; therefore, juvenile crabs would prefer fish bone, shelled molluscs and crustaceans (Cannicci *et al*. 1996; Williams 1982). The patterns of feeding ecology of juvenile and mature crabs are supported by bycatch data from collapsible crab traps and crab gill nets (Kunsook 2012). Moreover, differences in feeding between seasons and habitat types were found in this study because the abundance and distribution of prey differed for each season and habitat type. The species composition of the prey or the food of the crab is shown in detail by the bycatch composition (Fig. 11). The advantage of this research is that it can be used to solve problems in aquaculture, such as the identification of appropriate crab food items for each stage or the need for information that can be used in the restocking of this crab in its natural habitat.



(a)



(b)

Figure 11: Species composition of bycatch from (a) crab gill net and (b) collapsible crab trap for *P. pelagicus* in Kung Krabaen Bay, Chanthaburi Province.
Note: BSC – blue swimming crab

CONCLUSIONS

In summary, blue swimming crabs at Kung Krabaen Bay are predominantly carnivores and scavengers, feeding primarily on teleost fish and on invertebrate prey including molluscs and crustaceans. The results showed the differences between the feeding patterns of juvenile and mature crabs, which reflected an ontogenetic niche shift in this crab species.

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