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Species Diversity and Abundance of Marine Crabs (Portunidae: Decapoda) from a Collapsible Crab Trap Fishery at Kung Krabaen Bay, Chanthaburi Province, Thailand

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Abstract: The diversity and abundance of marine crabs from a collapsible crab trap fishery at Kung Krabaen Bay, Gulf of Thailand, were observed from August 2012 to June 2013 using 10 sampling stations. The results showed that there were seven families, 11 genera and 17 species (two anomuran and 15 brachyuran crabs). The two anomuran species were *Clibanarius virescens* (1,710 individuals) and *Clibanarius infraspinatus* (558 individuals). For brachyuran crabs, Portunidae was the most common family, including 10 species. The dominant species of brachyuran crabs included *Thalamita crenata* (897 individuals), *Portunus pelagicus* (806 individuals), *Charybdis affinis* (344 individuals), *Scylla* sp. (201 individuals), and *Charybdis anisodon* (100 individuals). The abundance of crabs was affected by the habitat type. Anomuran crabs had the highest abundance in *Halodule pinifolia* seagrass beds, whilst brachyurans had the highest abundance in *Enhalus acoroides* seagrass beds. The dominant brachyuran species were found in pelagic areas near the bay mouth, such as *P. pelagicus*, *P. sanguinolentus*, *C. feriatus*, *C. helleri*, *C. natator*, *C. affinis*, and *M. hardwickii*. Lastly, reforested mangroves were important habitats for *Scylla tranquebarica* and *C. anisodon*. Seasonal and physical factors influenced the abundance of some crabs, for example, the abundance of *C. virescens* was correlated with temperature, and the abundance of *T. crenata* was correlated with transparency depth. Our results revealed that Kung Krabaen Bay serves as the home to many marine crab species; however, our results also revealed that 49% of the harvested crabs (2,308 out of 4,694 individuals) were simply discarded and subsequently died. Moreover, our research noted that eight non-target species will become target species in the near future. Therefore, research on the reproductive biology of some marine crabs and an improved understanding of the importance of marine crabs by local fishermen are necessary to prevent biodiversity degradation and loss in this area.

Keywords: Species Diversity, Abundance, Marine Crabs, Collapsible Crab Trap, Kung Krabaen Bay

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INTRODUCTION

Marine crabs are economically important to Thailand. At a country level, they have long been exported to foreign countries in the form of living crabs and chilled crabs (e.g., Taiwan, Singapore, Hong Kong, Japan, China, the United States of America.). Some species such as the blue swimming crab, *Portunus pelagicus*, and the mud crab, *Scylla* sp., are well-known in international markets. At a local level, they are a source of income for local fishing communities living in coastal areas. From an ecological point of view, they play an important role as predators, prey, and/or detritus feeders in the complex food web of coastal and marine ecosystems, especially in mangrove forests, seagrass beds and coral reefs. At the same time, they are prey for other marine animals such as squids, fish, turtles and mammals (Josileen 2011).

Recently, the topic of marine crabs in Thailand has been an area of debate in terms of a variety of issues, especially regarding anthropogenic causes such as habitat destruction and degradation, environmental crises (e.g., pollution from oil spills), and overharvesting (Tiansongrassamee 2004). In many coastal areas, mangrove forests have been converted into shrimp farms that subsequently release pollution into the sea. This has a negative effect on the important nursery grounds of many marine animals. Some coastal areas have also been converted into tourism hotspots, creating pollution and waste that is then fed back into coastal and marine ecosystems. A further case to consider is unintentionally caught species, so-called “bycatch”, with a portion being marine crabs. Most of them are non-economic species and are usually discarded. As a result of these disturbances, many species of marine crab are currently threatened. Unfortunately, there has been limited study on the species diversity and ecology of marine crabs for conservation purposes.

Kung Krabaen Bay, one of the many fishing grounds in Thailand, has a number of diverse habitats, such as mangrove forests, seagrass beds and coral reefs (Kunsook *et al*. 2014b), which are suitable for many brackish and marine plants and animals. It is an important fishery site for fishermen to generate income, especially from the blue swimming crab. This area is currently a source of disagreement with regards to development problems, as mentioned earlier. Kung Krabaen Bay and adjacent sites (e.g., Chaolao and Kung Wiman beaches) are now popular places for tourism thanks to their long, beautiful beaches. In the last few decades, many resorts have emerged in parallel with road development projects for convenient access. In turn, this situation creates higher demand for crabs and other marine animals that is not only limited to the blue swimming crab as in the past.

Much research has been carried out in Kung Krabaen Bay, particularly on the blue swimming crab, including research on its feeding ecology (Kunsook *et al*. 2014a), stock assessments (Kunsook *et al*. 2014b: Bhatrasataponkul *et al.* 2008), population dynamics (Kunsook 2006; Raungprataungsuk, 2009) and sustainable management (Kunsook *et al*. 2014b, Tantichaiwanit *et al*. 2010) because it is this crab species that is the main target in this area. There are many different types of fishing gear used to harvest blue swimming crabs, such as crab gill nets, crab gill seines and collapsible crab traps. It was reported that there were more than 4,000 collapsible crab traps in this area alone and that they could potentially harvest other marine animals, including shrimps, squids, molluscs and fish (Kunsook 2011). As a consequence of the reduction in the numbers and size of blue swimming crabs due to overharvesting (Kunsook 2011; Kunsook *et al*. 2014b), fishermen have adapted to collecting and selling other marine animals, particularly marine crabs that are unintentionally caught by fishing gear, to gain further income. As a result, many of them have become new target species. This adaptation by the fishermen has created more pressure on marine animals, with many of them becoming new target species in the area.

The increase in harvesting pressure and tourist demand for marine animal products has led to issues regarding biodiversity degradation and biodiversity loss. Unfortunately, there has been limited study on the diversity and abundance of other marine crabs as well as their utilization by fishermen, i.e., those being discarded, consumed by the family, and/or sold. Such data are important for establishing an appropriate conservation plan. Therefore, this study aims to investigate the species diversity and physical factors related to the abundance and distribution of marine crabs from a collapsible crab trap fishery. The findings from this study will provide new scientific knowledge on the effects of collapsible crab trap fisheries on marine animals, which could be further applied towards biodiversity conservation in other coastal areas around Thailand and its neighbouring countries.

MATERIALS AND METHODS

Data Collection

The data were collected in Kung Krabaen Bay, which is located in Chanthaburi Province, eastern Thailand (Fig. 1). One hundred collapsible crab traps (28×46×18 cm) covered with a green polyethylene net with a mesh size of 2.5 inches were used to collect crab samples on a monthly basis from August 2012 to July 2013. These traps were placed in the sea for 4 hours during high tide using fish to attract crabs to the entrance of the trap. After four hours, the crabs were harvested and brought to the laboratory for analysis. This procedure was carried out over two seasons, wet and dry, based on the classifications of the Kung Krabaen Bay Royal Development Study Center (2003). The dry season lasted from November to April and the wet season from May to October.

The sampling sites were separated into 10 stations covering diverse types of crab habitats, including two species of seagrass, *Enhalus acoroides* and *Halodule pinifolia*, reforested mangrove forests and pelagic areas inside the bay (Fig. 1). Ecological factors were also measured with a multi-parameter probe (LEGA Engineering Company, Bangkok) at each station, including dissolved oxygen, temperature, pH, salinity, depth and transparency depth.

After the field data collection, the crab samples were identified by key references, including Virachapinthu (1989); Thamrongnawasawat & Wisespongpand (2007), and Singhacharoenwat *et al*. (2013). Then, the intended utilisation of the marine crabs (i.e., being discarded, consumed, and/or sold) was determined by interviewing the fishermen who had practiced collapsible crab trap fishing in the bay.

(a) (b)

Figure 1: Sampling sites in Kung Krabaen Bay, Thailand (A), and a collapsible crab trap (B).

Note: Habitat types: A-B = Reforested mangroves; C-E= *Enhalus acoroides* seagrass beds; F-G = *Halodule pinifolia* seagrass beds; H-J = Pelagic areas.

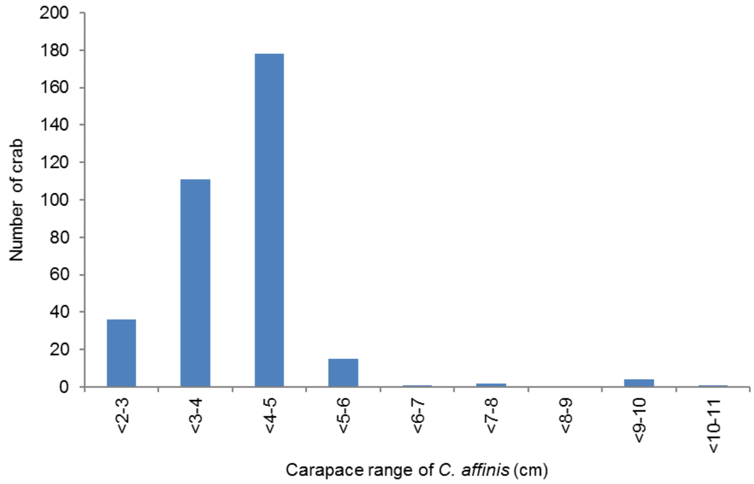
Data Analysis

The abundance of marine crabs amongst stations and seasons was compared by one-way ANOVA, and the percentages of those being discarded, consumed and/or sold were analysed. The relationships between the abundance of crabs and physical factors were also tested by Pearson correlations.

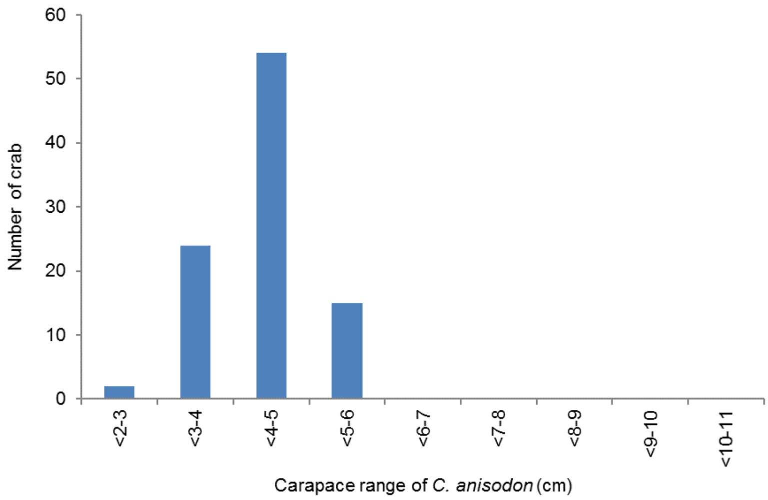
RESULTS

Species Diversity

The marine crab species diversity in the Kung Krabaen Bay ecosystem can be classified into seven families, 11 genera, and 17 species (Table 1). From the total number of 4,694 individuals, there were two anomuran species, *Clibanarius virescens* (1,710 individuals, 36.4%) and *Clibanarius infraspinatus* (558 individuals, 11.9%), and 15 brachyuran species, with a total of 2,426 individuals (51.7%). Most of the brachyuran crabs were members of the family Portunidae, which consisted of 10 species. The dominant brachyuran species were *Thalamita crenata* (897 individuals), *Portunus pelagicus* (806 individuals), *Charybdis affinis* (344 individuals), *Scylla tranquebarica* (201 individuals), and *Charybdis anisodon* (100 individuals). The size distribution of some marine crabs was observed, showing the average size of *P. pelagicus*, *S. tranquebarica T. crenata, C. affinis* and *C. anisodon* to be 7.17±2.29, 7.80±2.21, 5.51±1.08, 4.10±1.00 and 4.32±0.64 cm carapace width (CW), respectively. The carapace range of *P. pelagicus* was highest, ranging from 8–9 cm, while those of *S. tranquebarica* and *T. crenata* ranged from 9–10 cm and 5–6 cm, respectively. For both species of the genus *Charybdis*, *C. affinis* and *C. anisodon*, the highest carapace width ranged from 4–5 cm (Fig. 2). These results indicate that marine crabs in Kung Krabaen Bay are in the juvenile stage.

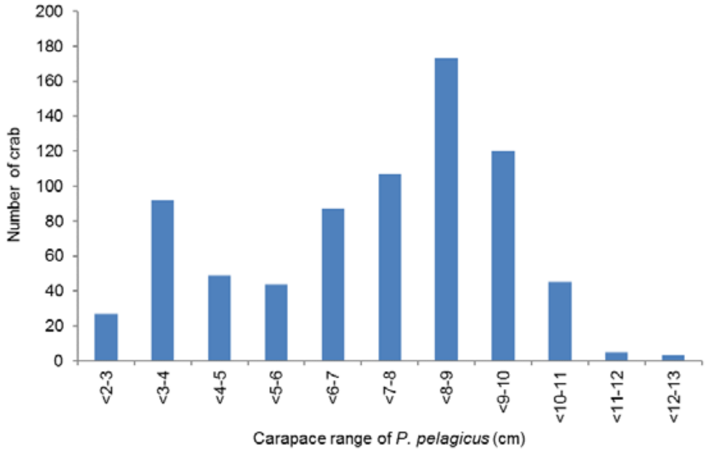


(a)



(b)

Figure 2: Size distributions of some marine crabs in Kung Krabaen Bay, Chanthaburi Province, Thailand. (*continued on next page*)



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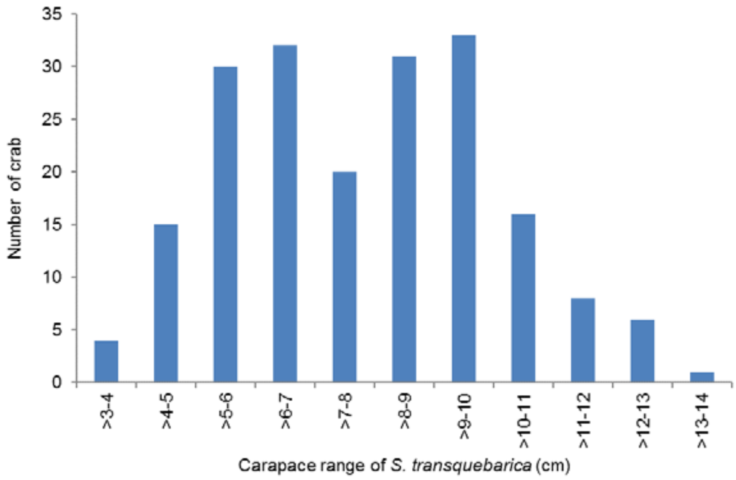

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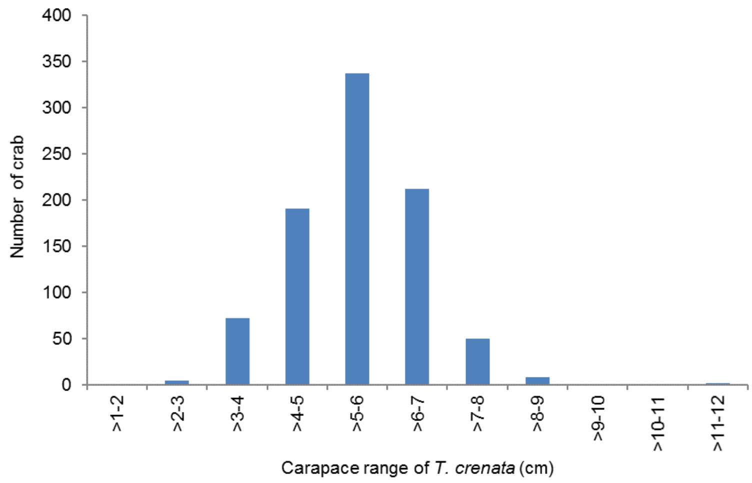


(e)

Figure 2: (*continued*).

Utilisation Status

Regarding the utilisation of marine crabs by fishermen, the results showed that seven species were discarded (2,308 individuals, 49%), including *C. infraspinatus*, *C. virescens*, *M. victor*, *H. diacanthus*, *C. helleri*, *P. vigil*, and *A. integerrimus*. Of these discarded species, most were anomurans (2,268 individuals, 48%), and very few of them were brachyurans (40 individuals, 1%) (Table 1, Fig. 3).

Ten species of marine crabs (2,386 individuals, 51%) were kept for household consumption and/or sale at local markets. Two of the species kept were the target species of collapsible crab trap fisheries in the study area (1,007 individuals, 22%), these being *P. pelagicus* and *S. tranquebarica*. The other eight species (1,379 individuals, 29%) were *V. litterata*, *M. hardwickii*, *C. affinis*, *C. anisodon*, *C. feriatus*, *C. natator*, *P. sanguinolentus*, and *T. crenata*. (Table 1, Fig. 3).

Based on the interviews and observations, the fishermen usually cooked marine crabs by making them sweet or fried and ate them as crispy snacks. These products are also popular among tourists who come to visit Kung Krabaen Bay and the beaches near this area.

Table 1: Species diversity of marine crabs in Kung Krabaen Bay, Thailand.

Family	Scientific name	Common name	Number of individuals	Utilisation*
Anomuran group				
Diogenidae	*Clibanarius infraspinatus*	Orange striped hermit crab	558	D
	Clibanarius virescens	Yellow foot hermit crab	1,710	D
Brachyuran group				
Calappidae	*Matuta victor*	Moon crab	29	D
Grapsidae	*Varuna litterata*	Green tidal crab	1	C/S
Majidae	*Hyastenus diacanthus*	Horn decorator crab	1	D
Menippidae	*Myomenippe hardwickii*	Stone crab	3	C/S
Portunidae	*Charybdis affinis*	Swimming crab	344	C/S
	Charybdis anisodon	Two-spined arm swimming crab	100	C/S
	Charybdis helleri	Indo-Pacific swimming crab	5	D
	Charybdis feriatus	Crucifix crab	10	C/S
	Charybdis natator	Ridged swimming crab	8	C/S
	Podophthalmus vigil	Long-eyed swimming crab	1	D
	Portunus pelagicus	Blue swimming crab	806	C/S
	Portunus sanguinolentus	Blood-spotted swimming crab	16	C/S
	Scylla tranquebarica	Mud crab	201	C/S
	Thalamita crenata	Rock crab	897	C/S
Xanthidae	*Atergatis integerrimus*	Brown shawl crab	4	D
		Total	4,694	

Note: * D = Discard, C = Consume, S = Sale

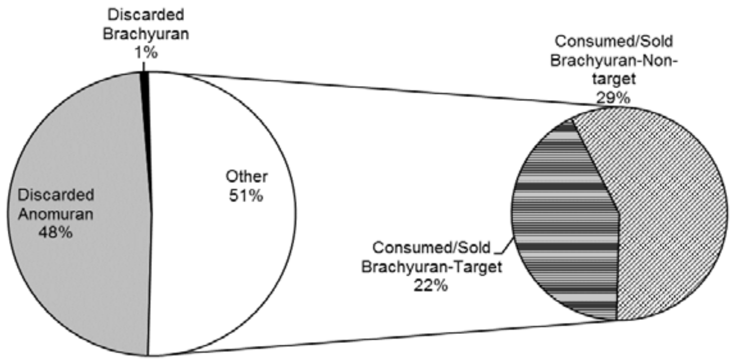
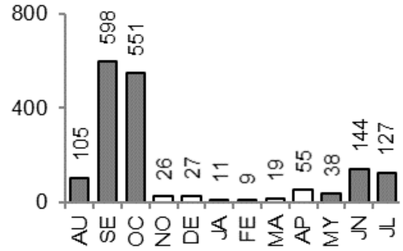


Figure 3: Utilisation statuses of marine crabs.

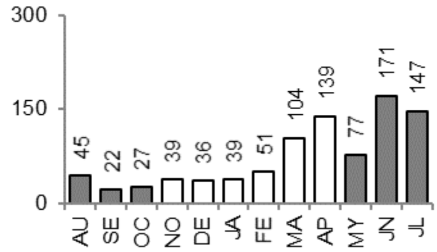
Seasonal Abundance

Most of the marine crabs, such as *T. crenata*, *P. pelagicus*, *C. affinis*, *S. tranquebarica*, and *C. anisodon*, were caught all year long, while some species were found in particular seasons, including *V. litterata* and *P. vigil*, which were caught in the wet season, and *H. diacanthus*, which was caught in the dry season (Fig. 4).

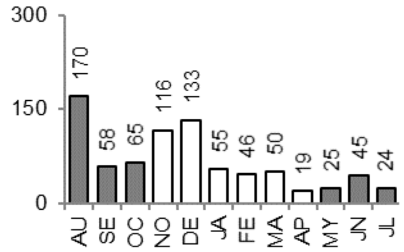
(a) Clibanarius infraspinatus



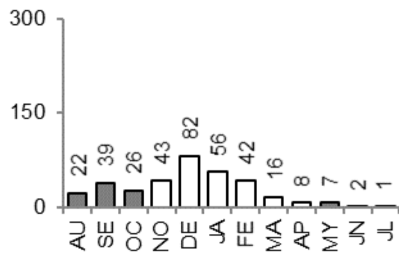
(b) Clibanarius virescens



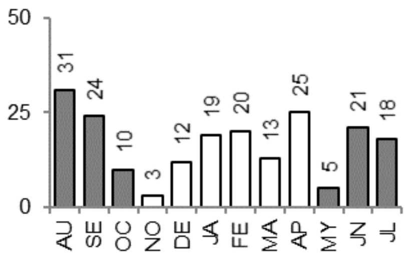
(c) Thalamita crenata



(d) Portunus pelagicus



(e) Charybdis affinis



(f) Scylla transquebarica

Figure 4: Seasonal abundances of marine crabs from August 2012 to July 2013 at Kung Krabaen Bay, Chanthaburi Province, Thailand. (*continued on next page*)

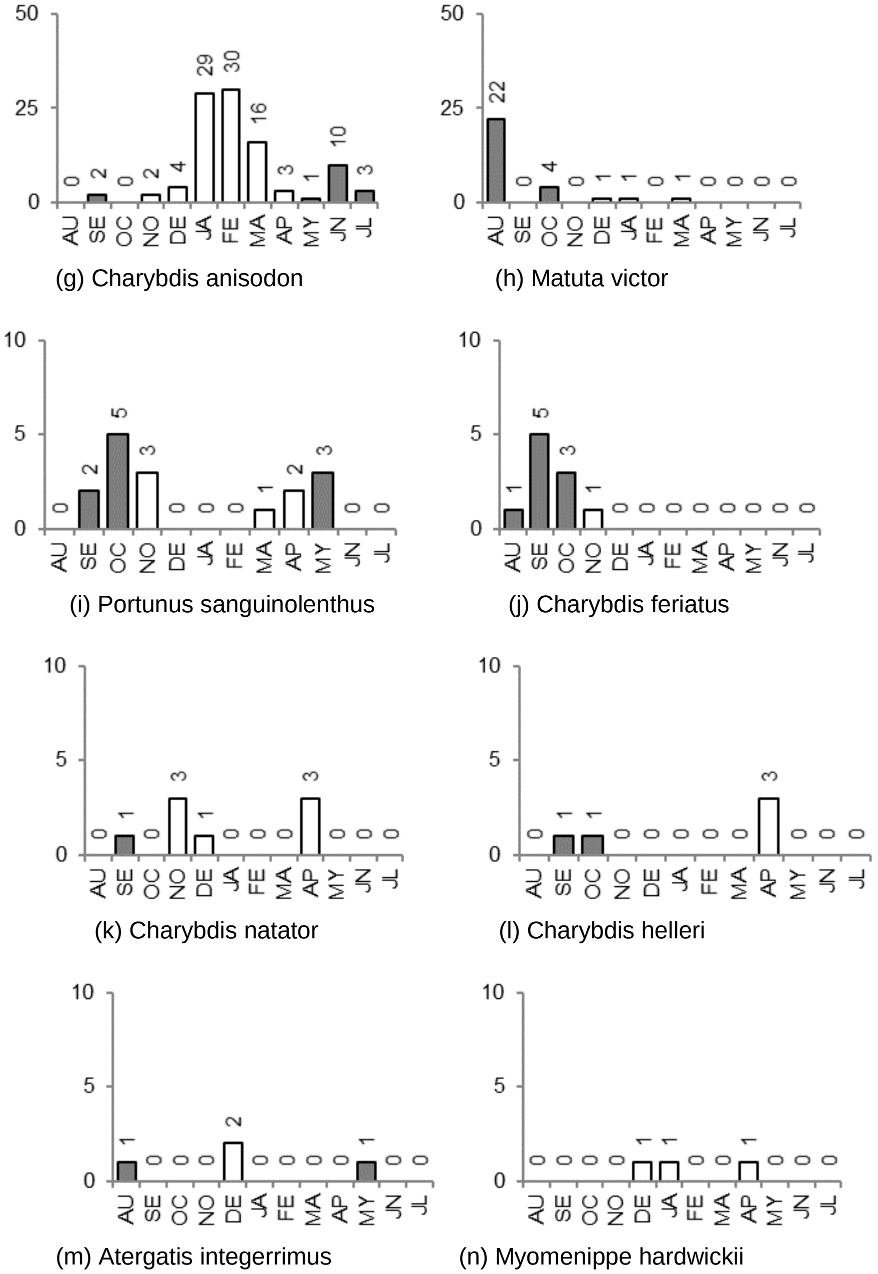
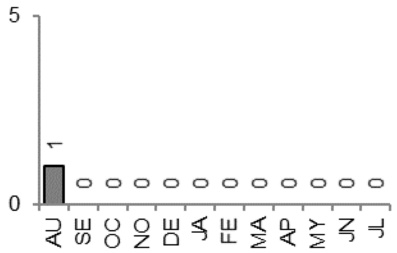
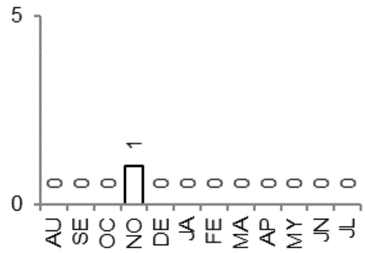


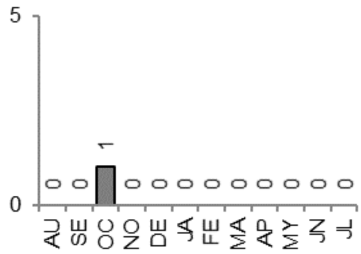
Figure 4: (*continued*).



(o) Valuna litterata



(p) Hyastenus diacanthus



(q) Podophthalmus vigil

Figure 4: (*continued*).

Going into further detail, the highest and lowest abundances of anomuran crabs were found in September (during the wet season) and February (during the dry season), respectively, (Fig. 4). *C. virescens* was common in September and October, whilst *C. infraspinatus* was common in July. Similar to brachyuran crabs, many other species were commonly found in the wet season, such as *P. pelagicus*, *P. sanguinolentus*, and *T. crenata*. Statistically, the numbers of *C. virescens, C. affinis* and *C. anisodon* were significantly different between the two seasons (Table 2).

Table 2: One-way ANOVA results showing the significance of differences in marine crab abundance between the wet and dry seasons.

Species of marine crab	Df	Mean square	F	Sig.
Clibanarius virescens	1	3641.008	7.558	.007*
Clibanarius infraspinatus	1	138.675	3.292	.072
Portunus pelagicus	1	72.075	1.471	.228
Thalamita crenata	1	572.033	5.752	.018
Scylla tranquebarica	1	3.333	.648	.423
Charybdis feriatus	1	0.675	2.916	.090
Portunus sanguinolentus	1	0.408	1.170	.282
Charybdis affinis	1	190.008	11.826	.001*

(*continued on next page*)

Table 2: (*continued*)

Species of marine crab	Df	Mean square	F	Sig.
Charybdis anisodon	1	43.200	11.725	.001*
Charybdis hellerii	1	0.008	.091	.763
Matuta victor	1	1.200	1.483	.226
Atergatis integerrimus	1	0.008	.337	.563
Myomenippe hardwickii	1	0.033	2.034	.156
Charybdis natator	1	0.008	.145	.704

Note: *Significance at $p<0.05$

Abundance among stations

Among our 10 sampling stations, we found that stations A and B were reforested mangroves; C, D and E were *Enhalus acoroides* seagrass beds; F and G were *Halodule pinifolia* seagrass beds; and H, I and J were pelagic zones. Regarding these four habitat types, the results showed that two anomuran species were distributed across all the recorded sites; however, they had the highest abundance in the *H. pinifolia* seagrass bed stations (stations F and G) followed by the pelagic zones (stations H, I and J). In further detail, *C. virescens* was most commonly found in *H. pinifolia* seagrass beds (Station E), while *C. infraspinatus* was found in the pelagic area near the mouth of the bay (Station H) (Fig. 5).

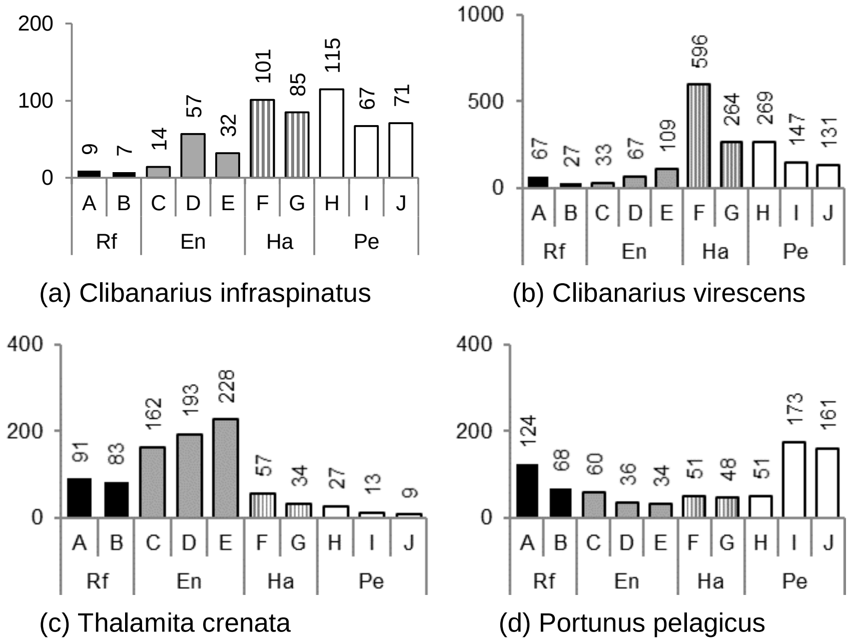
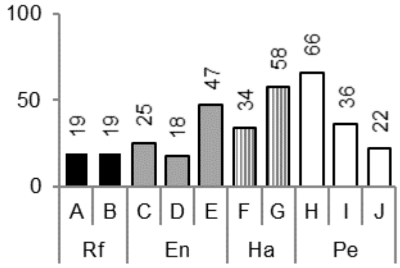
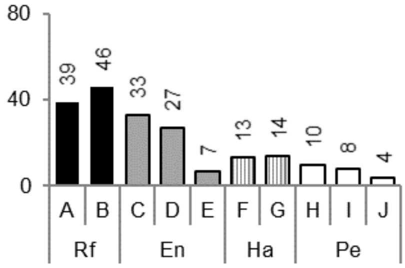


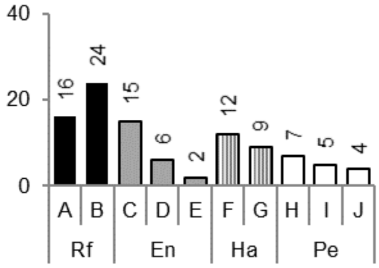
Figure 5: Abundance and distribution of marine crabs across 10 stations at Kung Krabaen Bay, Chanthaburi Province, Thailand. (*continued on next page*)



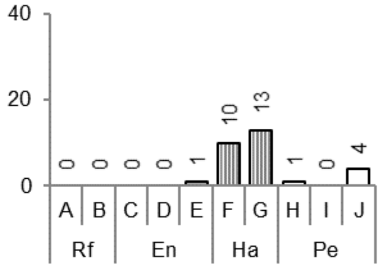
(e) Charybdis affinis



(f) Scylla transquebarica

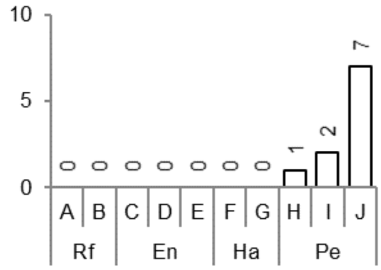


(g) Charybdis anisodon

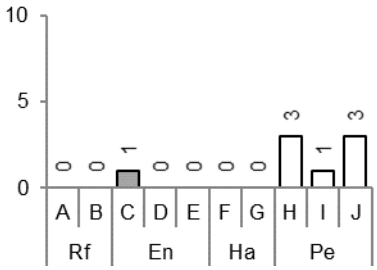


(h) Matuta victor

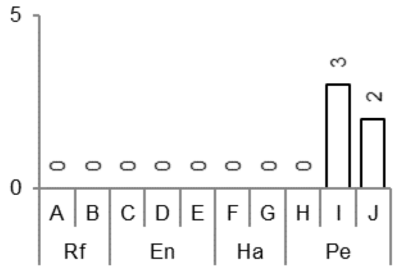
(i) Portunus sanguinolentus



(j) Charybdis feriatus

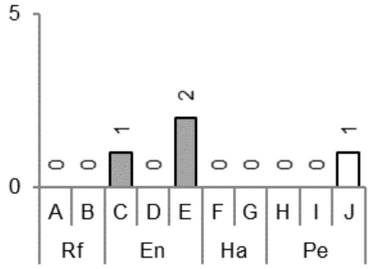


(k) Charybdis natator

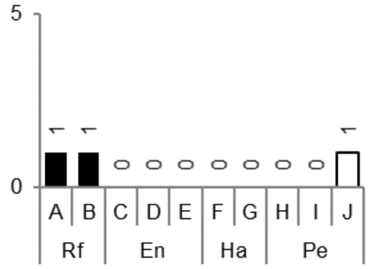


(l) Charybdis helleri

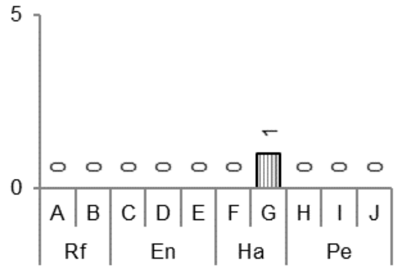
Figure 5: (*continued*)



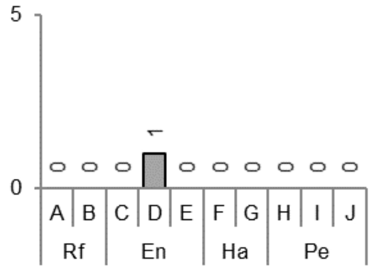
(m) Atergatis integerrimus



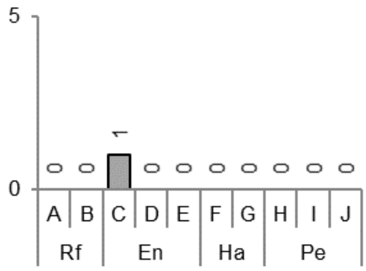
(n) Myomenippe hardwickii



(o) Valuna litterata



(p) Hyastenus diacanthus



(q) Podophthalmus vigil

Figure 5: (*continued*)

In the case of brachyuran crabs, six species, including *T. crenata, P. pelagicus, P. sanguinolentus, C. affinis, C. anisodon*, and *S. tranquebarica*, were distributed across all habitat types (Fig. 4). Some species, such as *P. pelagicus*, *P. sanguinolentus*, *C. natator, C. feriatus*, *C. helleri*, *C. affinis* and *M. hardwickii*, had the highest abundance in pelagic zones (stations H, I and J), whilst *T. crenata*, *A. integerrimus*, and *H. diacanthus* commonly inhabited *E. acoroides* seagrass beds. *M. victor* and *V. litterata* were found in *H. pinifolia* seagrass beds. *S. tranquebarica* and *C. anisodon* had the highest abundance in reforested mangrove forests. Statistically, the numbers of anomuran crabs (*C. virescens*) were significantly different ($p<0.05$) amongst the stations. For brachyuran crabs, the numbers of *P. pelagicus*, *P. sanguinolentus*, *T. crenata*, *Scylla* sp., *C. feriatus* and *C. natator* were also found to be significantly different ($p<0.05$) amongst the stations (Table 3).

Table 3: One-way ANOVA results showing the significance of differences in the abundance of marine crabs among stations.

Species of marine crab	df	Mean square	F	Sig.*
Clibanarius virescens	9	514.800	7.379	.000*
Clibanarius infraspinatus	9	63.379	1.536	.144
Portunus pelagicus	9	217.241	5.687	.000*
Thalamita crenata	9	514.800	7.379	.000*
Scylla tranquebarica	9	13.963	3.168	.002*
Charybdis feriatus	9	0.527	2.493	.012*
Portunus sanguinolentus	9	1.186	4.220	.000*
Charybdis affinis	9	27.582	1.651	.110
Charybdis anisodon	9	4.342	1.090	.376
Charybdis hellerii	9	0.097	1.078	.384
Matuta victor	9	0.870	1.078	.385
Atergatis integerrimus	9	0.059	1.222	.289
Myomenippe hardwickii	9	0.870	1.078	.385
Charybdis natator	9	0.134	2.645	.008*

Note: *Significance at level 0.05

Relationship between the abundance of crabs and physical factors

We found positive and negative correlations between the abundance of crabs and the physical factors for some species (Table 4). Among the anomuran crabs, *C. infraspinatus* had a positive correlation with temperature. In the brachyuran crabs, *T. crenata, S. tranquebarica*, and *P. sanguinolentus* had negative correlations with transparency depth, while *M. vietnamensis* showed an opposite relationship. *T. crenata* was negatively correlated with depth, whilst *C. helleri* showed a positive correlation. Only *A. integerrimus* showed a correlation with salinity. The other species, such as *P. pelagicus*, *C. affinis*, *C. anisodon* and *C. feriatus*, were found to have no correlation with physical factors, meaning that they were able to distribute widely in the bay. The average salinity was 27.25±4.68 PSU, the average temperature was 30.2±3.05°C, and the average pH was 7.60±1.11. The other physical factors are shown in Table 5.

Table 4: Correlation between marine crabs and physical factors in Kung Krabaen Bay.

Species of marine crab	Factor	Correlation value
C. infraspinatus	temperature	0.665
T. crenata	transparency depth and depth	-0.677 and -0.655
Scylla tranquebarica	transparency depth	-0.716
P. sanguinolentus	transparency depth	-0.666
M. vietnamensis	transparency depth	0.643
C. helleri	temperature and depth	0.644 and 0.743
A. integerrimus	salinity	-0.763

Table 5: Physical attributes of seawater in Kung Krabaen Bay.

Physical factor	Mean±SD.
Salinity	27.25±4.68 PSU
Temperature	30.2±3.05 °C
pH	7.60±1.11
Dissolved oxygen	6.38±1.29 Mg/L
Transparency depth	84.85±49.24 cm

DISCUSSION

Species Diversity

Kung Krabaen Bay has a size of approximately 760 ha, supporting seven families, 11 genera and 17 species of marine crabs (two anomuran and 15 brachyuran species) harvested from a collapsible crab trap fishery. This is in comparison to previous studies in Thailand showing that there are 746 species of marine crabs (Naiyanetr 1998; Ng & Davie 2002). In coastal areas, 54 species of marine crabs were found in Cape Panwa, Phuket Province (Wisespongpand *et al*. 2009), 54 species in Mu Ko Angthong Marine National Park, Surat Thani Province (Wisespongpand *et al*. 2008), and 77 species in Mu Ko Surin National Park, Thailand (Wisespongpand *et al*. 2007). Moreover, Khoyngam & Lauhachinda (1985) reported 11 families, 37 genera and 72 species of marine crabs from a small trawl fishery. Unfortunately, there is a lack of reports on species diversity in other bays around Thailand to compare with this study. However, we can confidently say that this could be an important area for preserving species diversity, as approximately one-fourth to one-third of marine crab species inhabit this bay alone, in comparison to other coastal areas of Thailand.

In other regions, Jit *et al*. (2013) reported that the majority of marine crabs found within a small-scale fishery in the Bay of Bengal were from the family Portunidae. Sakthivel & Fernando (2012) found a total of 38 brachyuran species at Mudasal Odai and Nagapattinam on the southeastern coast of India. Among these numbers, there were 19 species of portunid crabs. Our findings showed four of the same species, namely *C. hellerii, C natator, P. sanguinolentus and T. crenata*. Moreover, Varadharajan & Soundarapandian (2012) studied the diversity of commercially important crabs from Arukkattuthurai to Pasipattinum on the southeastern coast of India, where they found 12 species of crabs, the most dominant of which was *P. pelagicus,* similar to our own study. However, differences in the number of species were caused by many factors such as the habitat (bay or coastal areas), geographical distribution of the crabs, season, fishing gear used to collect the samples (Raungprataungsuk 2009; Kunsook 2011; Wisespongpand *et al*. 2009), exploitation rate and physical factors such as temperature, salinity, transparency depth and pH (Varadharajan & Soundarapandian 2012).

The size distribution results show that most of the marine crabs, such as *P. pelagicus, S. tranquebarica*, *T. crenata*, *C. affinis* and *C. anisodon*, were in the juvenile stage due to this area having many diverse ecosystems such as seagrass bed and mangrove ecosystems. Both ecosystems serve as habitat and nursery grounds for juvenile marine animals, particularly marine crab populations (Pittman & McAlpine 2003; Kangas 2000).

Abundance and Distribution Across Stations

This study found that the different habitat types had different suitability for marine crabs. Anomuran crabs, particularly *C. virescens,* had the highest abundance year-round in *H. pinifolia* seagrass beds. This corresponds with a previous study showing that anomuran species inhabit muddy and sandy beaches and intertidal to shallow sub-tidal seagrass bed areas in the Indo-Pacific region, which includes Thailand (Wait & Schoeman 2012).

Some brachyuran crabs such as *P. pelagicus*, *P. sanguinolentus*, *C. feriatus*, *C. helleri*, *C. natator, C. affinis* and *M. hardwickii* had the highest abundance in the pelagic areas (Stations H, I and J) due to their life cycle (Raungprataungsuk 2009; Kunsook 2011). The Kung Krabaen Bay ecosystem is an important nursery ground for juvenile crabs. They live in the bay until they grow to maturity before moving to the deep sea for spawning. Using the water current, the crab larvae (megalopa stage) will then settle in the bay again and mature (Kunsook *et al*. 2014b). Thus, we find these species in pelagic areas.

Other species such as *T. crenata*, *A. integerrimus*, *M. vietnamensis* and *H. diacanthus* had the highest abundance in *E. acoroides* seagrass beds, whilst *M. victor* and *V. litterata* were found in *H. pinifolia* seagrass beds. These two seagrass species cover large areas in the north-eastern and eastern parts of Kung Krabaen Bay. They play an important role in providing habitat for a variety of commercially and recreationally valued marine species, including marine crabs. Raungprataungsuk (2009) and Kunsook *et al*. (2014b) assessed the population of *P. pelagicus* in this bay. They found that 70% of crabs in this area are in the juvenile stage. Moreover, Tianpru & Samakphan (2014) investigated the species diversity of marine animals in the bay and found a total of 36 species. Importantly, they found many animals in the juvenile stage, including arthropods (95%), chordates (4%) and molluscs (1%), in both seagrass beds.

The highest abundances of *S. tranquebarica* and *C. anisodon* were found in reforested mangroves, similar to the report by Le Vay *et al*. (2007), who found the highest abundance of *Scylla* sp. in natural and reforested mangroves. The life cycle of *Scylla* sp. is similar to that of *P. pelagicus*. Mature female crabs will migrate to deeper areas to spawn (Pittman & McAlpine 2003). However, in general, this species inhabits mangrove forests by burrowing holes into the substrate. In the case of *C. anisodon*, this species was also found in reforested mangroves during this study. However, if *S. tranquebarica* is present, *C. anisodon* will not appear. This might be because the crabs will avoid competition for resources.

As presented above, each habitat plays an important role for different marine crabs. Therefore, conservation and management practices should take into account the spatial heterogeneity of the habitats in the bay, especially regarding the nursery grounds of marine crabs.

Seasonal abundance

The seasonal abundances of some marine crabs were found to be similar to those of other marine crabs in other areas. *C. virescens* dominated in the wet season, which was similar to the results of a study by Wait & Schoeman (2012), where they found that the abundance of this species was greatest in mid-July in Africa. Furthermore, our research found that brachyuran crabs, such as *C. affinis* and *C. anisodon*, were highest in abundance in the dry season. This result was similar to the findings of Chu (1999), showing that the greatest abundance of *C. affinis* ranged from March to April. Generally, portunid crabs can spawn year-round, so we can find all of them in each month, although their breeding season consists of two peaks. Despite their yearlong spawning habits, they have the highest abundance in the dry season (Chande & Mgaya 2003; Sara *et al*. 2006; Kunsook *et al*. 2014b).

Physical factors and abundance of marine crabs

Our results showed that temperature, transparency depth, depth, and salinity influenced the abundance and distribution of some species of marine crabs. *C. infraspinatus* and *C. helleri* were positively correlated with temperature; therefore, they tended to stay in areas with high temperatures (30–35°C) (Tiansongrassamee 2004). Some brachyuran crabs were found to be correlated with transparency depth and depth, i.e., *T. crenata*, *Scylla* sp., *M. vietnamensis, C. helleri* and *P. sanguinolentus*. These crab species usually inhabited intertidal areas, especially rocky shores and seagrass beds (Cannicci *et al*. 1996; Manmai *et al*. 2013). The transparency depth and depth that were suitable for these crabs ranged from 1–7 m. *T. crenata, Scylla tranquebarica* and *P. sanguinolentus* were usually found in shallower water with a depth of 1–2 m, whilst *M. vietnamensis* was usually found in deeper water at a depth of 3–4 m (Cannicci *et al*. 1996; Panishaphon *et al*. 2011). Only one species, *A. integerrimus*, showed a correlation with salinity. This species was usually found in low-salinity areas in the range of 28–30 ppt. In Kung Krabaen Bay, salinity is affected by fresh water inputs from small rivers around the bay, especially during the monsoon season, which lasts from May to October. Salinity not only influences distribution but also larval development by affecting the temperature (Kangas 2000; Pittman & McAlpine 2003; Kunsook 2011). Despite these results, the numbers of some species in this study, such as those of *P. pelagicus*, *C. affinis*, *C. anisodon and C. feriatus*, were found not to be correlated with physical factors. This was in contrast with a previous study (Kunsook *et al*. 2014b) showing that *P. pelagicus* is correlated with temperature and salinity. This difference might be related to seasonal variation and the local availability of marine crabs in each year (Potter *et al.* 1991).

Biodiversity Loss Problem

Our results clearly show that collapsible crab trap fisheries have negative effects on marine crab diversity in Kung Krabaen Bay, such as degradation and loss. In the case of anomuran crabs, this species is a major part of the bycatch of the collapsible crab trap fishery, as approximately 2,200 individual crabs were shown to be harvested per year (collected from 100 traps in this study out of approximately 4,000 traps used in the bay). They were usually discarded and would subsequently die in areas near housing after the selection process by fishermen of the target species, *P. pelagicus*. Over the long term, this human activity might create some negative effects on the Kung Krabaen Bay ecosystem because anomuran crabs play an important role. They are the main carnivores, scavengers and food for *P. pelagicus* in the food web (Chande & Mgaya 2004). Therefore, a reduction in these crabs will also affect the production of *P. pelagicus* and the structure and functions of the entire ecosystem. Moreover, these two species are distributed throughout the Indo-Pacific region (Siddiqui & Kazmi 2003), and overharvesting them in small areas may in turn affect the larger ecosystem.

In the case of brachyuran crabs, many species were harvested as bycatch, with an approximate number of 2,400 individuals harvested per year (from 100 traps). Some species, including *C. helleri*, *A. integerrimus*, and *M. vietnamensis*, were discarded, but other species, such as *T. crenata* and *C. affinis*, were kept for family consumption or for processing and sale at the market. In the past, only *P. pelagicus* and *Scylla* sp. were target species because they could be sold in the market at a high price and were commonly consumed in households. Currently, because of the reasons mentioned earlier in this paper, other brachyuran species have become new target species, especially *T. crenata*, *C. affinis*, and *C. anisodon*. This is supported by our results showing that the proportion of the harvested individuals of the target species, *P. pelagicus* and *S. tranquebarica*, and those of other brachyuran species was around two-thirds. As brachyuran crabs play an important role in estuary and marine ecosystems, similar to anomuran crabs, the changes in some brachyuran crab species from being non-target species to a new target species will lead to biodiversity loss issues in the near future.

Suggestions and Future Research

To avoid such problems, policy makers, researchers and local fishermen have to work together to improve the understanding of the importance of these marine crabs. Moreover, they have to collectively establish conservation and management strategies such as planting seagrass species to enlarge shelter areas and habitats for marine crabs, limiting the mesh size of collapsible crab traps to give a chance for juvenile crabs to grow to maturity before being targeted by fishing, and releasing non-target species back into the bay as soon as possible after harvesting the target species. In terms of research, studies on the reproductive biology (e.g., fecundity, first size at maturity and gonadosomatic index, etc.) and ecology (e.g., feeding and population dynamics) of marine crabs should be conducted, primarily on the dominant and tentatively new target species (e.g., *T. crenata*, *C. affinis*, and *C. anisodon*). This knowledge would be useful for the further establishment of suitable plans to sustain marine crab populations by, for example, limiting the size and number of crabs harvested, closing the bay in the spawning season, and limiting the mesh size of collapsible crab traps.

CONCLUSION

Research on the species diversity and abundance of marine crabs was carried out in Kung Krabaen Bay. In an area of 760 ha, there were found to be seven families, 11 genera and 17 species of marine crab (two anomuran and 15 brachyuran crabs). A total of 4,694 individual crabs were harvested by collapsible crab traps, with 48% being anomuran and 52% being brachyuran species. The dominant anomuran species was *C. virescens*, whilst the dominant brachyurans were *T. crenata*, *P. pelagicus*, *C. affinis*, *Scylla tranquebarica*, and *C. anisodon*. These crabs inhabited different habitat types, with *C. virescens*, *M. victor*, and *V. litterata* being commonly found in *H. pinifolia* seagrass beds; *T. crenata*, *A. integerrimus*, and *H. diacanthus* being commonly found in *E. acoroides* seagrass beds; and *S. tranquebarica* and *C. anisodon* being commonly found in reforested mangroves. Therefore, protecting and enlarging seagrass beds and mangrove forests is important for species diversity conservation.

Overall, our results revealed that other marine crabs that became target species for fishing in this area accounted for 30% of the catches, while the target species (*P. pelagicus* and *S. tranquebarica*.) accounted for 21%. Moreover, 49% of the crabs were discarded. This continued situation will lead to biodiversity loss issues in this area. Therefore, biological study and an improved understanding by local fishermen regarding the importance of marine crabs in the ecosystem are necessary. Finally, we plan to create a simple gaming and simulation tool in the form of a board game and participatory field workshops to facilitate knowledge based on our findings and to explore feasible management strategies with a group of collapsible crab trap fishermen and local authorities, focusing on biodiversity degradation issues in this area.

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