JSTR
ASEAN Journal of Scientific and Technological Reports

Research article

Diversity, Abundance and Population Structure of Shore Crabs (Decapoda: Brachyura; Menippidae, Eriphidae, Xanthidae, Oziidae) at Nom Sao Island, Chanthaburi Province, the Eastern Gulf of Thailand

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Citation:
Kunsook, C. ; Karinthanyakit, W. Diversity, Abundance and Population Structure of Shore Crabs (Decapoda: Brachyura; Menippidae, Eriphidae, Xanthidae, Oziidae) at Nom Sao Inland, Chanthaburi Province, the eastern Gulf of Thailand. *ASEAN J. Sci. Tech. Report.* **2021**, *23(3)*, 15-26.

Article history:
Received: March 15, 2021
Revised: September 11, 2021
Accepted: October 6, 2021
Available online: December 28, 2021

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Abstract: Research on the diversity, abundance and population structure of shore crabs (Decapoda: Brachyuran: Menippidae, Eriphidae, Xanthidae, Oziidae) at Nom Sao Island, Chanthaburi Province, was conducted for a period of around nine months in 2019, starting in January through to May and then continuing from September to December. The study area focused on four ecosystems: sand beaches, rocky shores, coral reefs, and bare ground. Specimens were collected via collapsible crab traps, driftnets and free-hand methods. Species identification was made in both external and internal morphology consideration. The result found that species diversity of shore crab belonged to 4 families, 6 genera and 9 species. One species of Menippidae (*Myomenippe hardwickii*), two species of Eriphiidae (*Eriphia ferox* and *E. sebana*), three species of Oziidae (*Ozious guttatus*, *O. rugulosus* and *Epixanthus frontalis*) and three species of Xanthidae (*Leptodius nigromaculatus*, *Atergatis integerrimus* and *Atergatis floridus*) were found. The highest dominant species was *L. nigromaculatus* (280 individuals/square meter, 53.33%). Moreover, the rocky shore was found highest diversity (9 species) with the highest abundance of xanthid crabs. The highest abundance of nine crabs was found in April (130 individual/square meter, 24.76%), but in contrast, *A. integerrimus* was found the whole year. In addition, the ratio between male and female crab was 1:0.46. Carapace size distribution was found in the highest range 11-20 mm. The relationship between the abundance of shore crabs and ecological factors was significantly different with transparency depth ($P < 0.05$).

Keywords: Diversity, Abundance, Population Structure, Shore Crab, Nom Sao Island, The Eastern Gulf of Thailand

1. Introduction

Shore crabs play an important economic and ecological role in Thai coastal communities. In terms of their economic value, species of shore crabs, such as the blue swimming crab (*Portunus pelagicus*), has long been exported to various countries across Asia, North America and Europe [1] due to their high nutritional value and mineral content, as well as for their excellent taste [2]. In terms of their

ecological role, shore crabs are a significant part of coastal ecosystem food chains and are thus crucial in controlling ecological functions [3]. Some crab species have an essential role in species composition and population structure [4]. Because of this, many studies are conducted onshore crabs as bioindicators for monitoring both abiotic and biotic factors in coastal ecosystems.

Nowadays, direct and indirect impacts from high-intensity human activities, such as fishery overexploitation, pollution from aquaculture purposes and eco-tourism, have led to global climate change [5]. Shore crabs have been declining in diversity and abundance, especially for species with no market value, such as rock crabs or stone crabs. Shore crabs are key indicators for monitoring ecosystem disturbances due to their relevancy to the structure and function of particular ecosystems [3]. The morphology of these crabs are diverse and there are limited studies in this area. Nom Sao Island is a vital travel location of Chanthaburi Province. The local government recently supported and promoted the province itself as an eco-tourism location [6]. Tourists usually go diving, swimming and fishing on the island. The previous study assessed the number of tourists that visit Nomsao Island by about 4,798 people/year [5]. As a result, large amounts of garbage and pollution have impacted the island's various ecosystems [5]. During a previous study in 2016, the diversity of shore crabs in this area consisted of 14 families, 28 genera and 47 species [7]. A subsequent study in 2017 found the diversity of the place to be 19 families, 28 genera and 37 species [5]. This research aims to study the diversity, abundance and population structure of shore crabs in Nom Sao Island's ecosystems, focusing on rock crabs and stone crabs. By analysing their numbers, diversity, size and abundance in each ecosystem and season, the study will examine the relationship between the abundance of shore crabs and some ecological factors. This research will monitor and determine the impact human activities have had on the area, particularly eco-tourism.

2. Materials and Methods

2.1 Sampling and identification

Sampling was conducted for around nine months in 2019, starting in January through to May and then continuing from September to December, in four of Nom Sao Island's ecosystems: sand beaches, rocky shores, coral reefs, and bare ground (Figure 1). Nom Sao Island is located in the Lamsing district of Chanthaburi Province along the Eastern Gulf of Thailand (coordinates 12°29′17.1′′N, 102°03′49.4′′E). In coral reefs and bare ground, specimens were collected via fifty collapsible crab traps (28x46x18 cm) (a mesh size of 2.5 inches). For the sand beaches and rocky shores, three-line transects (200 m) were conducted at three regions: low tide, mid tide, and high tide using driftnets and free-hand methods [4]. Crab specimens were preserved with 10% formalin and transferred to the zoology laboratory of Rambhai Barni Rajabhat University's Department of Biology, Faculty of Science and Technology. The morphology of the crabs, such as sex, carapace width, carapace length and weight, were recorded and their species-level identified by several keys [8-14]. The digital camera photographed different morphologies and characteristics on both the anterior and posterior sides (Fujifilm version Fujifilm XA5). However, due to the external morphology of these crabs being similar, particularly xanthid crabs such as *Leptodius* sp. (Figure 2), the researcher also identified the crab species by using the characteristics of male characteristics gonopods [10, 12].

2.2 Data analysis

The population structure of the shore crabs was also analysed. Sex ratio was tested by chi-square and the abundance of crabs in each ecosystem and month was calculated individual/square meter and analysed via a one-way ANOVA test [9, 15]. Size distribution was calculated monthly by measuring the crabs' carapace width (mm). Relationships between shore crab abundance and ecological factors were analysed by a Pearson correlation at a significance level of 0.05.

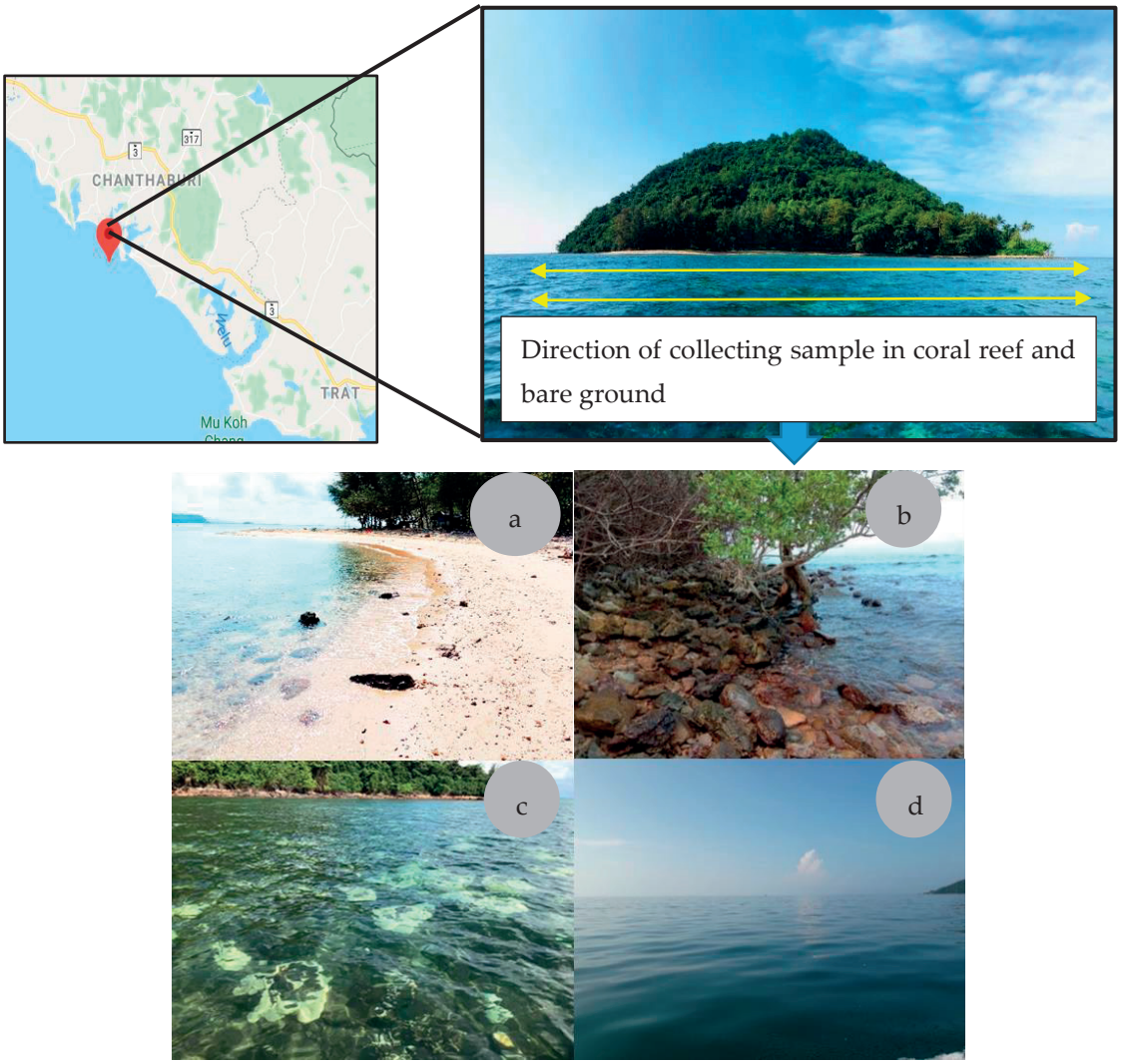

Figure 1. Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand (a) sand beach, (b) rocky shore, (c) coral reef, (d) bare ground

3. Results and Discussion

3.1 Diversity and abundance

The results found that from 525 specimens across all ecosystems, there were four families, six genera and nine species. Of these, one species was identified as Menippidae: *Myomenippe hardwickii*; two species as Eriphiidae: *Eriphia ferox* and *E. sebana*; three species as Oziidae: *Ozious guttatus*, *O. rugulosus* and *Epixanthus frontalis*; and a further three species as Xanthidae: *Leptodius nigromaculatus*, *Atergatis integerrimus* and *Atergatis floridus* (Figure 3). Studies on the abundance and distribution of these crabs found that *L. nigromaculatus* had the highest overall abundance (280 individuals/square meter ($m^{2)}$, 53.33%) followed by *Epixanthus frontalis* (94 individual/m^2, 17.90%), *Atergatis integerrimus* (52 individual/m^2, 9.90%), *Ozious guttatus* (34, 6.48%), *Myomenippe hardwickii* (31 individual/m^2, 5.90%), *Eriphia ferox* (24 individual/m^2, 4.57%), *Ozious rugulosus* (7 individual/m^2, 1.33%) and *Atergatis floridus* (1 individual/m^2, 0.19%), respectively (Table 1). Moreover, the result also showed that rocky shore ecosystems had the highest diversity of crabs (9 species), including the highest abundance of shore crabs (472, 89.90%), while coral reef, bare ground and sand beach ecosystems had lower abundances 27 (5.14%), 18 (3.43%) and 11 (2.10%), respectively.

Regarding overall distribution, six of the crab species resided in the rocky shore ecosystems of Nom Sao Island. These included *Eriphia ferox*, *E. sebana*, *Ozious guttatus*, *O. rugulosus*, *Epixanthus frontalis* and *Atergatis floridus*. It was observed that these six species did not migrate or move to other ecosystems throughout the study. In contrast, the other three shore crabs, *Myomenippe hardwickii*, *Atergatis integerrimus* and *Leptodius nigromaculatus*, migrated during the wet season over broad areas get to different ecosystems (Figure 4). The highest abundance of crabs was recorded in April and May (24.76% and 22.67%, respectively), whereas the lowest abundance was found in November (2.48%). *A. integerrimus* occurred all year round, particularly during February, while *L. nigromaculatus* occurred for seven months, especially in April and May. Statistical analysis showed that the abundance of crabs was significantly different each month ($P < 0.05$).

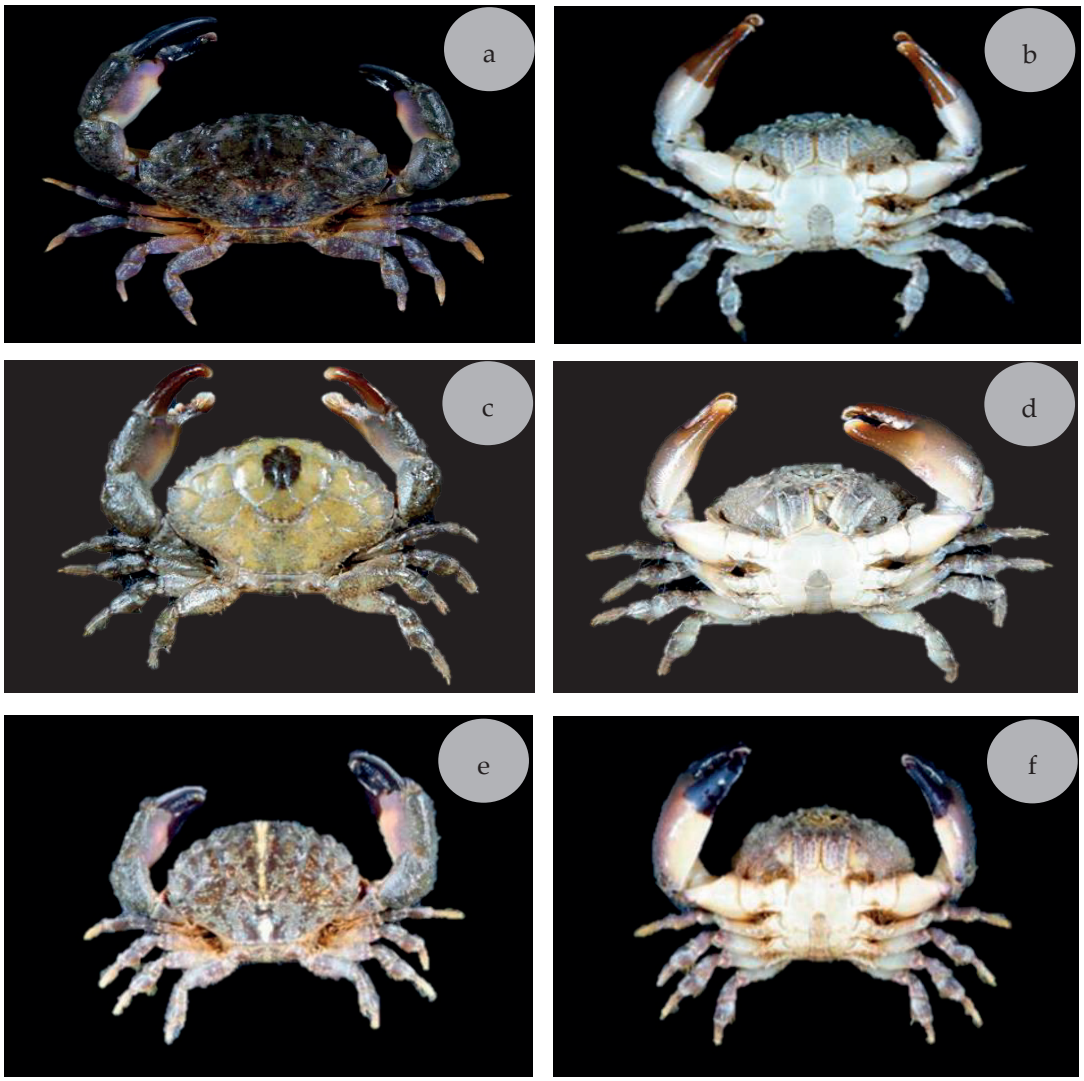

Figure 2. Variation in the external morphology of xanthid crab (*Leptodius* sp.) (a) (c) and (e) dorsal view of *L. nigromaculatus*, (b), (d) and (f) ventral view *of L. nigromaculatus*

3.2 Population structure and ecology

The population structure and ecology of the shore crabs were also studied, covering sex ratio, carapace size distribution and size distribution between males and females, and their relationship with physical factors in their habitat. The sex ratio between males and females was found to be 1:0.46. This showed that male crabs had a higher population than females ($P < 0.05$). However, when observing all of the crab species collectively, there were only two, *A. integerrimus* and *L. nigromaculatus*, which had a proportion of males higher than

females (P < 0.05), whereas for the other species, male crabs had no significant difference from female crabs and were recorded as 1:1 (P > 0.05) (Table 2).

Table 1. Diversity and abundance of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Family	Genus	Scientific name	Status	No. of crabs (%)
Menippidae	*Myomenippe*	1) *Myomenippe hardwickii*	Dominant	31 (5.90)
Eriphiidae	*Eriphia*	1) *Eriphia ferox*	Dominant	24 (4.57)
		2) *Eriphia sebana*	Rare	2 (0.38)
Xanthidae	*Atergatis*	1) *Atergatis integrrimus*	Dominant	52 (9.90)
		2) *Atergatis floridus*	Rare	1 (0.19)
		3) *Leptodius nigromaculatus*	Dominant	280 (53.33)
Oziidae	*Ozious*	1) *Ozious guttatus*	Dominant	34 (6.48)
		2) *Ozious rugulosus*)	Rare	7 (1.33)
	Epixanthus	3) *Epixanthus frontalis*	Dominant	94 (17.90)
Total				**525 (100)**

Table 2. Sex ratio of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Scientific name	Male	Female	Total	(Expected value)	χ2	Ratio
Atergatis integerrimus	37	15	52	26	4.65*	1 : 0.41
Leptodis nigromaculatus	206	74	280	140	31.11*	1 : 0.36
Epixanthus frontalis	53	41	94	47	0.77	1 : 0.77
Myomenippe hardwickii	17	14	31	16	0.16	1 : 0.16
Ozious guttatus	24	10	34	17	2.88	1 : 0.42
Ozious rugolosus	5	2	7	4	0.71	1 : 0.71
Eriphia sebana	1	1	2	1	1	1 : 1
Atergatis floridus	1	0	1	0	0	1 : 0
Eriphia ferox	15	9	24	12	0.75	1 : 0.6
Total	**359**	**166**	**525**	**263**	**35.48***	**1 : 0.46**

Note: * significant at 0.05 level

Carapace size distribution of shore crabs ranged from 11-20 mm (Figure 6) and size distribution in each species was recorded (Figure 7). *A. integerrimus* and *M. hardwickii* have grouped as large xanthid crabs with a carapace size larger than 50 mm (55.52 ± 22.81 mm and 66.94 ± 16.20 mm, respectively). The smallest size of xanthid crab was *L. nigromaculatus* at 18.56 ± 5.71CW mm. Average carapace width in other shore crabs, such as *E. ferox*, *E. sebana*, *O. guttatus*, *O. rugolosus* and *E. frontalis*, was recorded as 42.84 ± 16.83 mm, 37.96 ± 14.26 mm, 34.07 ± 14.96 mm, 32.70 ± 10.06 mm and 28.30 ± 7.21, respectively (Table 3). Regarding *A. floridus*, only one specimen was found for this species, so it could not be accurately recorded or considered within the whole population. For carapace size distribution per sex, the results divided the crabs into two groups. The first group consisted of more giant male crabs than females, including *L. nigromaculatus*, *M. hardwickii* and *O. rugolosus*. The second group consisted of larger females than their males, which included *A. integerrimus*, *E. frontalis*, *O. guttatus* and *E. ferox*. The relationship between shore crab abundance and ecological factors was

differed based on transparency depth ($P < 0.05$) (Table 4). The highest abundance of crabs was found in a transparency depth of 0.30-0.38 m (Figure 8).

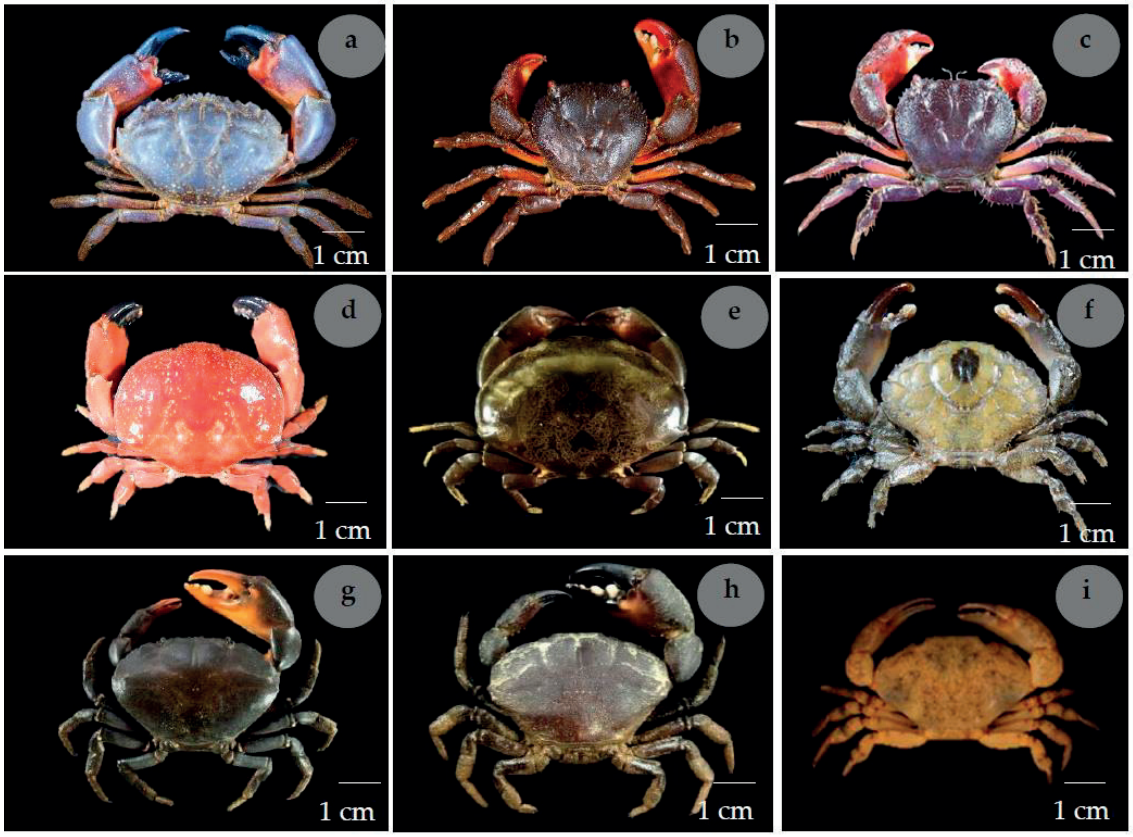

Figure 3. Species diversity of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand: (a) *M. hardwickii*, (b) *E. ferox*, (c) *E. sebana*, (d) *A. integerrimus*, (e) A. floridus, (f) *L. nigromaculatus*, (g) *O. guttatus*, (h) *O. rugolosus*, (i) *E. frontalis*

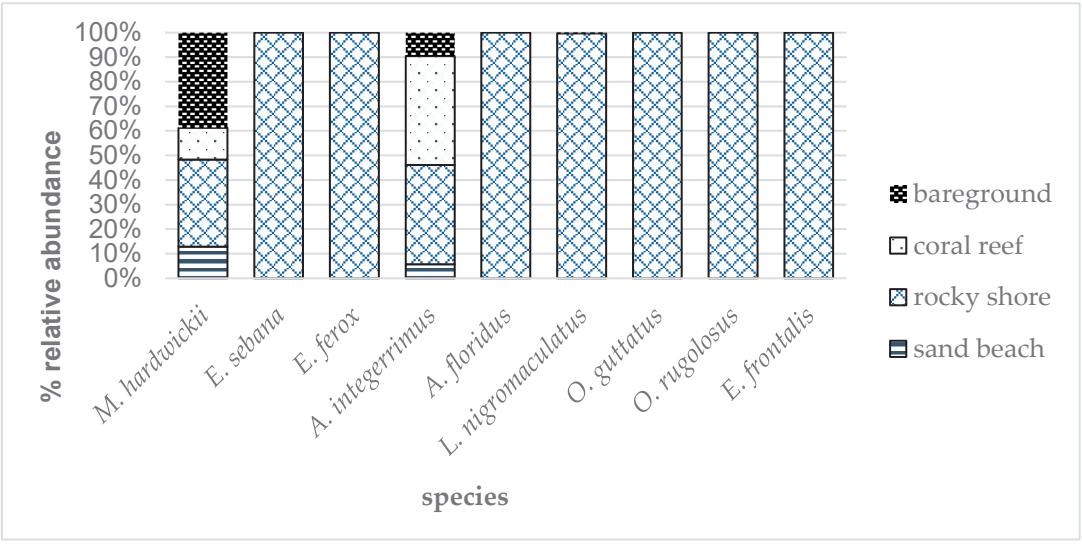

Figure 4. Distribution of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

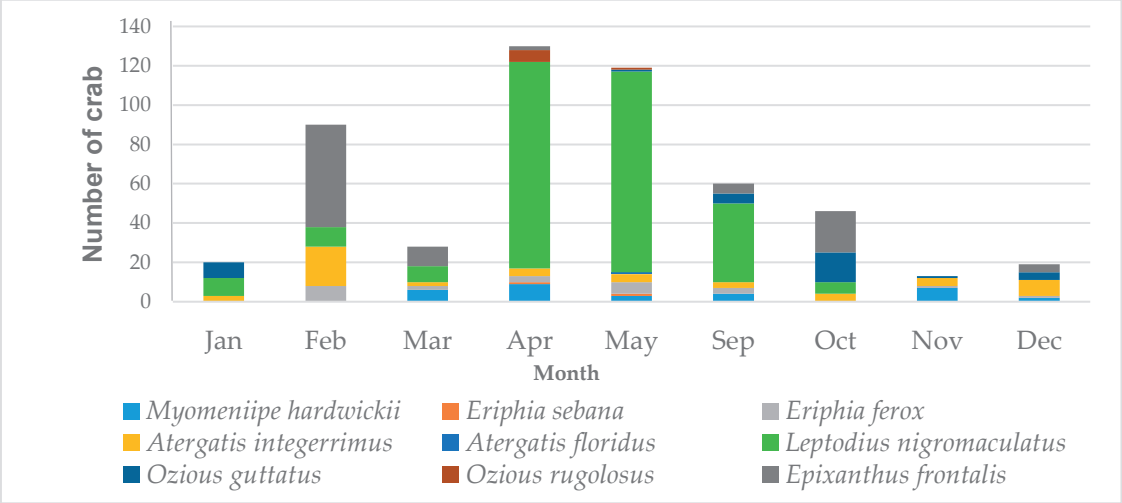

Figure 5. The monthly abundance of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

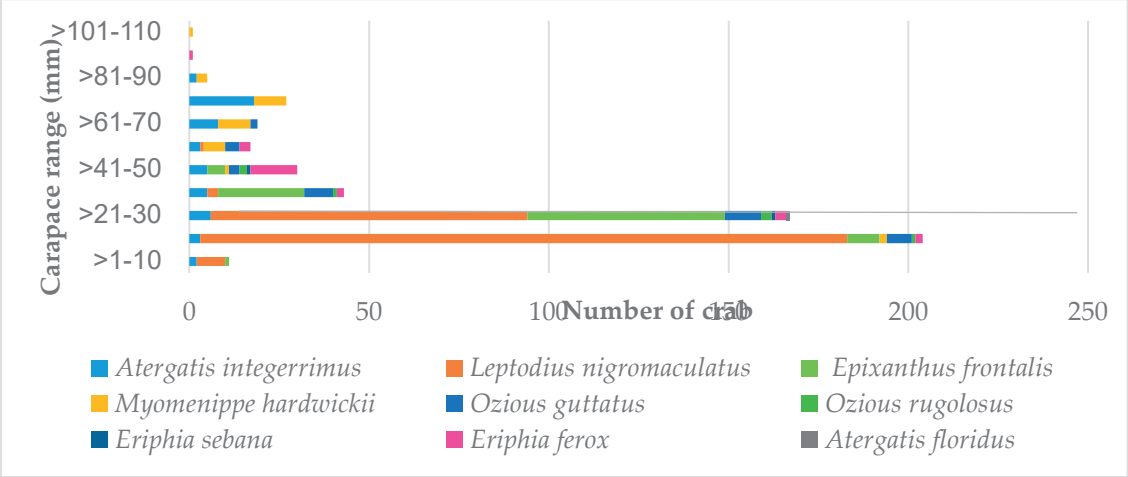

Figure 6. Carapace size distribution of shore crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Table 3: Average carapace width and length of crabs at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Species	CW range (mm)	CL range (mm)	CW average (mm)	CL average (mm)
Atergatis integerrimus	8.60-83.14	6.70-58.15	55.52 ± 22.81	38.78 ± 14.55
Leptodius nigromaculatus	3.60-53.69	3.40-84.80	18.56 ± 5.71	13.43 ± 7.29
Epixanthus frontalis	7.15-48.71	5.28-37.19	28.30 ± 7.21	21.11 ± 6.07
Myomenippe Hardwickii	23.81-101.90	18.05-71.46	66.94 ± 16.20	48.85 ± 11.39
Ozious guttatus	13.41-65.93	10.18-53.6	34.07 ± 14.69	27.41 ± 12.61
Ozios rugolosus	19.58-44.49	2.29-30.5	32.70 ± 10.06	17.31 ± 8.55
Eriphia ferox	13.27-99.25	9.99-51.52	42.84 ± 16.83	30.83 ± 10.69

Note * grey bar: Male was a larger size than female

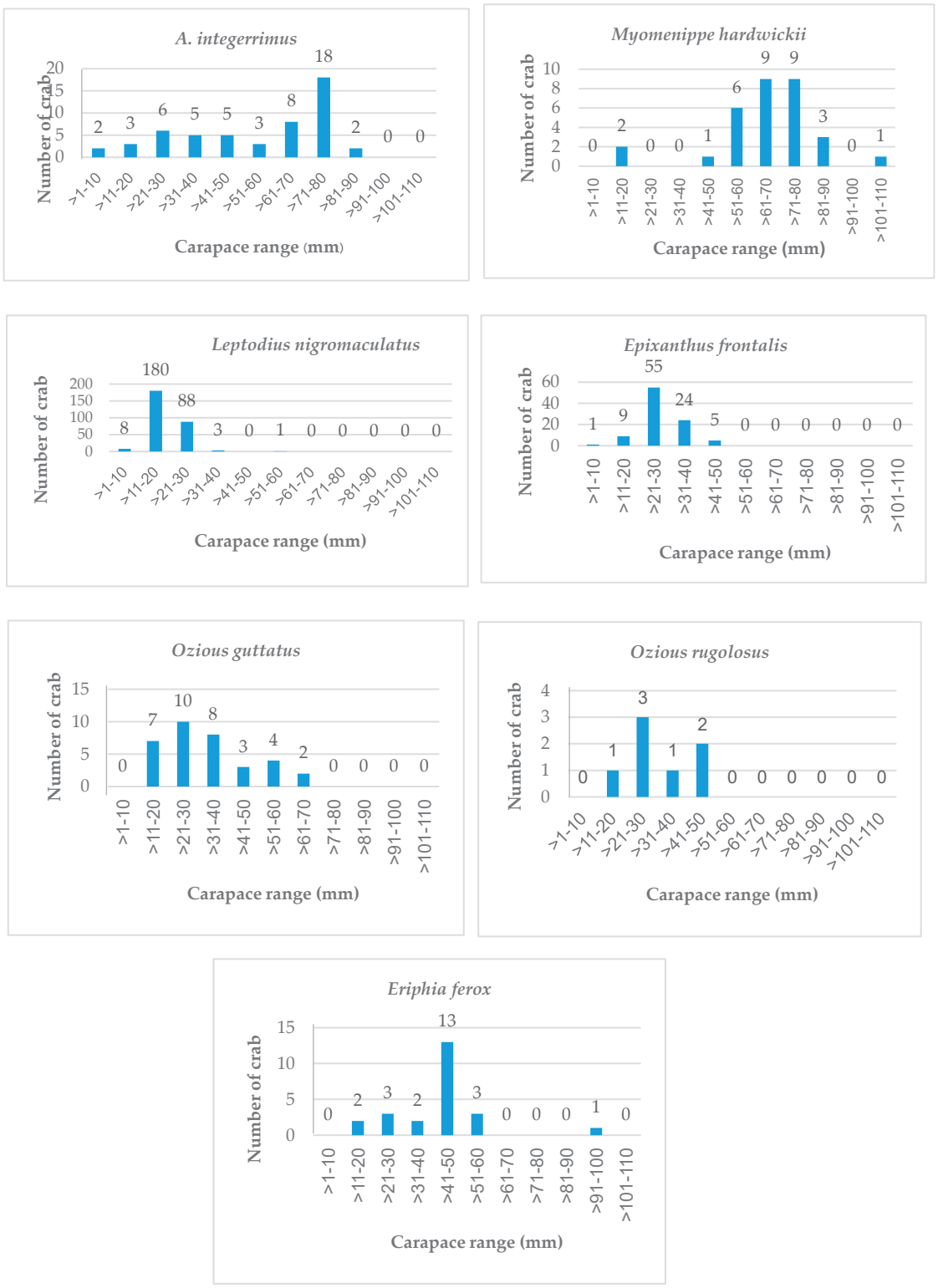

Figure 7. Carapace size distribution of each shore crab species at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Table 4. Correlation between abundance of shore crabs and ecological factors at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

Ecological factors	Range of value	Average±SD.	Pearson's correlation
Depth (m)	0.78-1.10	0.96 ± 0.14	-0.238
Transparency depth (m)	0.28-0.38	0.34 ± 0.04	0.612*
Salinity (ppt)	27.70-31.00	29.49 ± 1.16	-0.28
pH	6.70-8.80	8.00 ± 0.74	0.066
Dissolved oxygen (Mg/L)	4.00-5.90	5.01 ± 0.62	-0.216
Water temperature (°C)	29.00-32.00	30.49 ± 0.97	-0.192
Air temperature (°C)	30.00-32.00	30.78 ± 0.83	-0.15
Light intensity (Lux)	37,275.00-82,718.75	63,612.74 ± 14,307.04	-0.207

Note * Significant at level 0.01

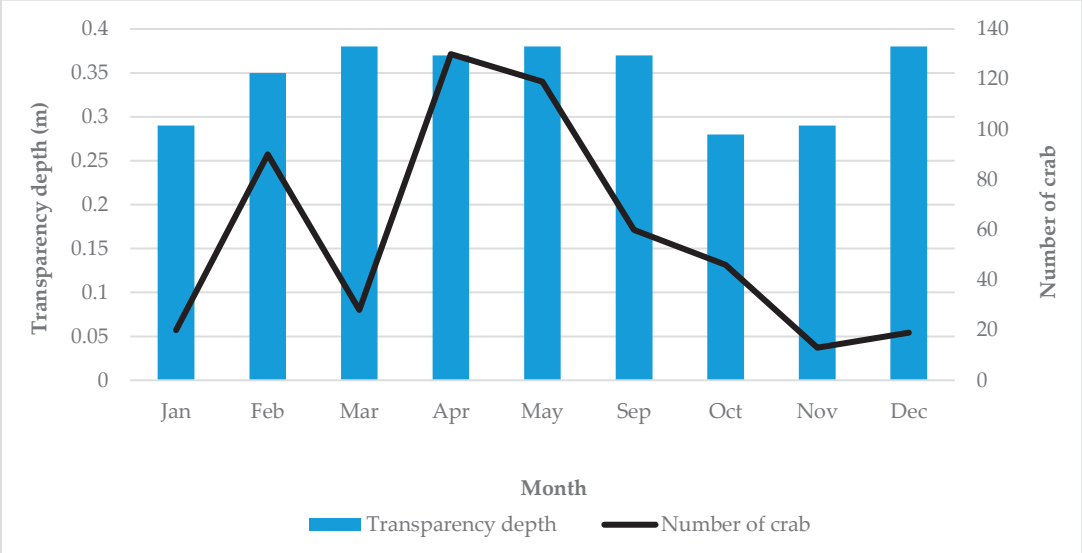

Figure 8. Relationship between the abundance of shore crabs and transparency depth at Nom Sao Island, Chanthaburi Province, Eastern Gulf of Thailand

The result of the diversity of crab species in this study was compared with the species recorded in the previous study [16]. It was found that there had been a reduction of 4 families, 8 genera and 13 species. This reduction of shore crab species shows that some species, such as *Platypodia alcocki* and *Etisus leavimanus*, have disappeared in the time taken between these two studies (the sampling method applies the same principles as [7, 17]). It is purported that the promotion of tourism in the area and the increasing number of tourists on the island have disturbed the habitats of these shore crabs. In addition, the increased amounts of garbage and pollution from human activity have changed physical factors in the water. Main fishing gear of the local community, such as collapsible crab trap fisheries and crab gill net fisheries, is another factor contributing to the reduction of shore crabs. When the fishermen harvest their target species, they can also reap the shore crabs as bycatch. Shore crabs often make up a significant proportion of bycatch from blue swimming crab fisheries [9]. Therefore, the local government and other stakeholders should consider an effective long-term management plan for conserving the crab population and their habitats to support continued biodiversity as an essential economic foundation. Having a high diversity of crabs has benefited the abundance and functionality of ecosystems and their health [18].

Rocky shore ecosystems provide the most remarkable species diversity and abundance of shore crabs due to their ideal location for food and their various types of habitats, such as algal cover [4] and shelter for growing and survival, including certain physical factors [19]. These all reasons why from the result of abundance was not found migration of shore crab in the rocky shore. Moreover, the highest abundance of shore crabs in rocky shore ecosystems was found during the mid tide, with high tide following and the lowest numbers recorded during low tide. This correlates with the result of previous researchers [4, 7], who also found a high abundance of these crabs at mid-tide. The mid-tide of rocky shore ecosystems was found to be the most suitable zone for foraging by these crabs due to phytoplankton and seaweed, such as red algae, brown algae and green algae being natural foods for them [20]. From studies, the seaweed in this area was found to belong to four species, *Padina pavonica*, *Sargassum binderi, Ulva intestinalis* and *Caulerpa lentillifera* [21]. In addition to being a source of food, the seaweed also served as shelter and a way to escape from predators. In high tide, the diversity and abundance of shore crabs decreased due to physical factors such as insufficient light, temperatures and low humidity during ebb tide, whilst low-tide zones faced additional factors such as erosion that further impacted species abundance [4].

The distribution of crabs throughout the year in each of Nom Sao Island's ecosystems was driven by many factors, such as predation risk, age, foraging behaviours and spawning season. This correlates with [18], which specifies that the distribution pattern of shore crabs may be affected by many factors, such as habitat preferences, food, infection of pathogens, and genetic inheritance. The highest abundance of crabs per month was found in April and May, whereas in November, the lowest abundance was found. *A. integerrimus* occurred all year round, with exceptionally high numbers in February, while *L. nigromaculatus* occurred for seven months, especially during April and May. The previous study reported that shore crabs in these families would have been spawning during the late wet season (September to December). It takes 3-4 months to grow to maturity and mate, after which it will have reached the peak of the dry season (March to April) [22].

This research reveals that male shore crab populations are higher than female crabs, especially *A. integerrimus* and *L. nigromaculatus*. The result was related to the previous study stating that males of these two species are more elevated than females at Mu Koh Mun in Rayaong Province and Mu Ko Samaesarn, Chonburi Province [16, 23]. The sex ratio between males and females is an indicator for forecasting trends in the crab population because the proportion of females influences the hatching rate. The hatch rate will also be below [24]. Variations in the sex ratio of crab species are influenced by various factors, such as season, migration and climate change, which can affect ecological factors such as temperature and salinity [25]. Female crabs do not spawn in high temperature and salinity areas. Optimal temperatures are around 27-33 °C, whereas salinity should be about 28-32 ppt [9].

Moreover, further analysis of carapace size distribution revealed that shore crabs could be divided into two groups. In the first group, male crabs are more giant than their female counterparts; these include *L. nigromaculatus*, *M. hardwickii* and *O. rugolosus*. In the second group, the female crabs are more larger than the males; these include *A. integerrimus*, *E. frontalis*, *O. guttatus* and *E. ferox*. Differences in the sizes of the crabs may be from several factors such as maturity, foraging behaviour and refuge from predators [3, 26]

4. Conclusions

This research reveals the diversity, abundance and population of shore crabs in the ecosystems of Nom Sao Island, an important eco-tourism location of Chanthaburi Province on the Eastern Gulf of Thailand. Crab species was sampled focused on four ecosystems: sand beaches, rocky shores, coral reefs and bare ground. Species identification was made in both external and internal morphology consideration. The result found that species diversity of shore crab belonged to 4 families, 6 genera and 9 species. The highest dominant species was *L. nigromaculatus* (280 individuals/square meter, 53.33%). Moreover, the rocky shore found the highest diversity (9 species), including the highest abundance of xanthid crabs. The highest abundance of nine crabs was found during the dry season in April (130 individual/square meter, 24.76%), but in contrast, *A. integerrimus* occurred all year round. In addition, the number of male crabs was higher than females indicated that 1:0.46. Carapace size distribution was found in the highest range 11-20 mm. The relationship between the abundance of shore crabs and ecological factors was significantly different with transparency depth ($p < 0.05$). However,

the result of these observed some shore crab families are not vulnerable. They still have an important role in the structure and function of coastal ecosystems. Moreover, this research emphasizes that shore crabs are an effective bioindicator for monitoring ecosystem health due to their prompt responses to environmental factors, including abiotic and biotic factors. In summary, they can maintain, modify and regulate coastal ecosystems. Therefore, human activities from promoted eco-tourism ventures should have a sustainable long-term management plan to help conserve these kinds of crabs.

5. Acknowledgements

This research was funded by Rambhai Barni Rajabhat University and the National Research Council of Thailand (Grant number 1112/2562). We would like to extend special thanks to Mr. Boonlert Boonmana, Chief Executive of the SAO of Bangkachai Subdistrict, for supporting Nom Sao Island's secondary data and kindly making several helpful suggestions throughout our research.

Author Contributions: Both authors contributed to the writing and conceptualizing of the work. CK wrote the original draft, and WK super-vised the manuscript.

Funding:

Conflicts of Interest: The authors declare none of the competing financial interests could appear to influence the work reported in this paper.

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