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Department of Ecology

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Abstract

The mangrove forest is one of the world's most threatened ecosystems today and they have decreased significantly in Southeast Asia over the past 40 years. Brachyura (crabs) are important for this ecosystem and they function as ecosystem engineers with their burrowing activities that affects the soil and carbon uptake. There are several factors that can have an impact on the abundance of crabs, two of these are environmental variables or human disturbance factors. Previous studies show that the occurrence and abundance of different crab species can be affected by the type a vegetation in the mangrove forest. The shade from the canopy has also been found to affect the occurrence of some crabs from the steady physical environment that canopy generates. Studies on the effect of human disturbance on the occurrence and abundance of the crab species in this study have not previously been done. The four species that are examined in this study are *Scylla serrata* (mud crab), *Uca vocans* (fiddler crab), *Sesarma mederi* (mangrove crab) and *Perisesarma bidens* (red claw crab), that live in the study area of Pranburi Forest Park, on the east coast of Thailand. For these species currently little is known about their habitat requirements and if, and how, they are affected by environmental and human disturbance factors. The environmental variables that were used in the analyze was the amount of three different tree species (*Rhizophora apiculata, Ceriops tagal, Avicennia marina*), water depth and canopy shade. The factors I used to estimate human disturbance was closeness to information signs, resting places and presence of road or river. The results of this study indicate that some species have a higher abundance than others, the sesarmids crabs*, S. mederi* and *P. bidens*, have a higher abundance than *S. serrata* and *U. vocans*. *U. vocans* was not included in the analyze because lack of individuals discovered in the fieldwork. I found that the three species analyzed are affected by both environmental variables and human disturbance. More individuals of *S. serrata* was found where there was a high water depth, a high percentage of canopy shade and less individuals were found in the presence of *A. marina* and close to the road and river. More individuals of *S. mederi* was find where there was a high water depth, a high percentage of canopy shade, where *R. apiculata* ware present and close to the river. More individuals of *P. bidens* was found where there was a high water depth, a high percentage of canopy shade and far away from the road, information signs and resting places. What could be done by park management to preserve the mangrove forest and the crab species is to plant *R. apiculata* when reforestation is done and not to cut down trees if the purpose is to maintain a high biodiversity. To reduce number of visitors in the park, opening hours could be set up, though it now is open around the clock.

Keywords: mangrove forest, Thailand, biodiversity, canopy shade, water depth, human disturbance, Brachyura, *Scylla serrata, Uca vocans, Sesarma mederi, Perisesarma bidens,*

Sammanfattning

Mangrove skogen är idag ett av världens mest hotade ekosystem och har minskat signifikant i Sydost Asien de senaste 40 åren. Brachyura (krabbor) är viktiga för ekosystemet då de fungerar som ekosystem ingenjörer med deras grävande aktiviteter som påverkar markens kolupptagning. Det är flera aspekter som kan ha en påverkan på abundansen av krabbor, det kan t.ex. vara miljövariabler eller störningsfaktorer från människan. Det har visats att förekomst och abundans av olika krabbarter påverkas av vilken typ av vegetation som växer i mangroveskogen. Det har också visats att skuggan från lövverket har en effekt på krabbornas abundans då lövverket genererar en stadig fysisk miljö. Det har inte gjorts några studier på om mänskliga störningar påverkar förekomst och abundans av krabbarter vilket kommer undersökas i denna studie. De fyra arterna som undersöks i denna studie är *Scylla serrata* (mangrovekrabba), *Uca vocans* (fifflare krabba), *Sesarma mederi* (Meder´s mangrovekrabba) och *Perisesarma bidens* (röd-klokrabba), som alla lever i det studerade området i Pranburi Forest Park, på östkusten i Thailand. För dessa arter är det nuvarande ganska lite känt om vilka habitat typer de föredrar och om de påverkas av miljövariabler och mänsklig störning. Miljövariablerna som användes i analysen var dominansen tre olika arter av träd (*Rhizophora apiculata, Ceriops tagal, Avicennia marina*), vattendjup och skugga av lövverket. Faktorerna som användes som mänsklig störning var närhet till informations skyltar, viloplatser såsom bänkar och närvaro av bilväg eller flod. Resultaten från denna studie visar på att vissa arter har en högre abundans än andra, *S. mederi* och *P. bidens* hade en högre abundans än *S. serrata* och *U. vocans*. U. vocans var inte inkluderad i analysen då väldigt få individer hittades vid fältarbetet. Studien visar på att de tre analyserade arterna påverkas av både miljövariabler och av de mänskliga störningsfaktorerna. Fler individer av *S. serrata* hittades där det va ett större vattendjup, en hög procent av skugga från lövverket och färre individer hittades vid närvaro av *A. marina* och nära till väg eller flod. Fler individer av *S. mederi* hittades där det var ett större vattendjup, en hög procent av skugga från lövverket, där *R. apiculata* fanns, samt ett litet avstånd till floden. Fler individer av *P. bidens* hittades där det var ett större vattendjup, en hög procent av skugga från lövverket och långt ifrån vägen, informations skyltar och viloplatser. För att bevara mangrove skogen och därmed krabborna kan de som sköter om parken tänka på att plantera *R. apiculata* då denna art gynnar krabbor, samt även tänkta på att inte hugga ner för många träd om målet är att upprätthålla en hög biodiversitet. För att minska antalet besökare i parken kan öppettider sättas upp, då parken för nuvarande är öppet för besökare dygnet runt.

Nyckelord: mangrove skog, Thailand, biodiversitet, skugga av lövverk, vattendjup, mänsklig störning, Brachyura, *Scylla serrata, Uca vocans, Sesarma mederi, Perisesarma bidens,*

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1 Introduction

The mangrove forest helps to stabilize soil and reduce the risk of coastal erosion, it acts as a filter for sediments and pollutants from the water on the way to the sea. The mangrove forest is an important carbon sink and is therefore important for the climate (Alongi, 2002). The biotope is one of the most productive terrestrial ecosystem in the world and its products are used for fuel, building materials, for medicines, in beekeeping, and as an area for hunting and fishing. The ecosystem absorbs and binds carbon dioxide to the sediment, which can help to reduce global warming. Mangrove forests also have an essential function for the mainland as it protects from storms and tsunamis, as the trees and roots slow down strong winds and waves by capturing the energy from these. (FAO, 1994).

The mangrove forest is one of the world´s most threatened ecosystem today. The loss of habitat comes from rivers being dammed and the water being redirected (FAO, 1994). Mangrove forests have decreased significantly in Southeast Asia over the past 40 years. The main reasons for the decrease in Southeast Asia have been urbanization and population pressures from humans, conversion to agriculture and salt production plus wood extraction. The overall biggest reason for the loss of mangrove habitat in many countries is from shrimp farming. The mangrove forest is cut down to make way for the farms. This industry gives a direct but also an indirect negative impact on the mangrove as shrimp farming damages nearby mangroves by leaking chemicals from the crops. In the mangrove ecosystem, the wetlands surrounding it are important parts of the ecosystem, and vary from being completely dry to water-filled. From this, they become an important part of the hydrological and chemical cycle. Despite this importance for the function of the water cycle, shrimp farming often occurs in these wetlands, which in turn destroys the mangrove even more (Macintosh *et al.,* 2002). The loss of mangrove forest is also a threat against the different crab species that lives there as they lose their habitat and food source.

Brachyura (crabs) represent the main heterotrophic biomass and energy in mangrove systems. The different species are important for the system as their burrowing

activity affects the soil and carbon uptake (Costa *et al.,* 2015). Organic detrital substance is produced in amounts from mangrove waste, and is believed to form the trophic basis for multiple food chains in the mangrove systems. There are studies done that shows that some mangrove crabs remove up to 30-90 % of the yearly litter fall by eating or by burial activities (Kristensen, 2008). Ecosystem engineers, such as mangrove crabs are therefore an important driver for structuring fauna communities in the mangrove (Kon *et al.,* 2010). The crab species function as ecosystem engineers through burrowing activities. By their burrowing activities they expand sediment drainage, they translocate the sediment and nutrients in them. They change the sediments erosion limit and also they expand the sediment surface area, this applies especially for *U. vocans* (Kristensen, 2008; Botto & Iribarne, 2000). Several aspects of the mangrove forest can have an impact on the presence of crabs. These can be factors related to the vegetation, different crab species are shown to be affected by the types of plants in the mangrove forest (Bandibas *et al.,* 2016). One example is the tree *Rhizophora apiculata,* where higher number of crab individuals has been found in its presence. This believed to be due to that *R. apiculata* is a food source for several crab species (Diele *et al.,* 2012). The shade in the mangrove has been found to affect the distribution of crabs. The canopy generates a steady physical environment with controlled variations in temperature and high moisture content in the sediment (Kon *et al.,* 2010), that may be beneficial for many different species.

Disturbance from humans (either directly or indirectly) may also affect crab presence (Kelaher *et al.,* 1998). This can be from for example boardwalks in mangrove that can have a negative influence on crabs. Disturbance factors that comes from boardwalks is for example the removal of trees, compaction of sediment and human disturbance as noise when using the boardwalk (Kelaher *et al.,* 1998). S. serrata is seen as food in Thailand and are sold on food markets in Hua Hin in Thailand (own observations), therefore fishing could be another disturbance factor from humans but are not included in this study.
Previous studies have found that juveniles of one of the species, *S. serrata*, have shown to be dependent on both water depth and shade (FAO, 2011). The needs of the other three crab species are unknown. Studies on the effect of human disturbance on the presence and abundance of these crab species has not been done previously and will be explored in this study.

In this study, I examine the occurrence and abundance of four different crab species: *Scylla serrata* (mud crab), *Uca vocans* (fiddler crab), *Sesarma mederi* (mangrove crab) (Fig. 1) and *Perisesarma bidens* (red claw crab) (Fig. 2) that are living in the mangrove forest. The study is conducted in a mangrove forest in Pranburi Forest

Park on the east coast of Thailand, near the Gulf of Thailand. For these species currently little is known about their habitat requirements and if they are affected by factors related to human disturbance.

The main questions of my study are:

- Is the abundance of crab species correlated to; environmental variables such as water depth, vegetation, canopy shade and indicators of human disturbance?
- Is there any difference between the species in how their occurrence and abundance are affected by the environment and disturbance variables?

Figure 1. Sesarma mederi
(Photo: Johanna Rosenquist 2017)

Figure 2. Perisesarma bidens
(Photo: Johanna Rosenquist 2017)

2 Material & methods

2.1 Study area

Pranburi Forest Park (latitude: 12° 24' 59.99" N, longitude: 99° 59' 1.79" E) is located in Thailand in Pranburi district in the province of Prachuap Khiri Khan (Fig. 3). Pranburi Forest Park protects the mangrove forest in Khlong Khao Khlong Kob National Reserve Forest and is situated at the mouth of the Pranburi River next to the Gulf of Thailand. An area of 3.17 km^2 of this forest park has been developed into a mangrove rehabilitation project under the initiative of Queen Sirikit. It was declared a protected forest park by the Royal Forest Department in 1982. The study was conducted between April 3 – April 16th 2017. This period is one of Thailand's three seasons, the hot and dry season of the year, with high temperatures between 25 – 40 ° C. The observational studies have been carried out along a 1,1 km long elevated walking trail inside the park (Fig. 4).

2.2 Study species

Pranburi Forest Park is habitat for several different species of animals, including four species of crabs. These species are *Scylla serrata* (mud crab*), Uca vocans* (fiddler crab), *Sesarma mederi* (mangrove crab) *and Perisesarma bidens* (red claw crab).

U. vocans is a detrivore and its main food source is bacteria. *U. vocans* is seen as an ecosystem engineer in mangrove system due to that they are screening the sand and air the substrate and thereby prevent anaerobic conditions (Costa *et al.,* 2015). Fiddler crabs have been found to live in the open areas in mangrove, especially in the places where sunlight is so strong that it is stimulate growth of microphytobenthos, which is one of the primary food source for this species (Kristensen, 2008).

S. mederi and *P. bidens* are both in the family Sesarmidae and the sesarmids food source is mainly leaf litter and therefore they have been found to have the biggest abundance under tree canopies. Some studies have shown that litter eating and burial by sesarmids might remove up to 30-90 % of the yearly litter fall. The roots from

mangrove trees protect the sesarmids against predators and extreme temperatures that may occur (Kristensen, 2008).

S. serrata is a mud crab that has it habitat burrowed down in the mud in mangrove forest and can therefore be hard to see. They want to have a high salinity in the water and can stand reduced salinity for some time but not for long. The main food source for *S. serrata* is marine detritus, molluscs and fish (FAO, 2011).

2.3 The mangrove system

Mangrove is considered a tidal habitat found in the tropical and subtropical countries along protected and shallow waters. Pneumatophores, a specialized structure developed from the root of special tree species that grow in swamps or marshes, acts as the respiratory tract. Prop-roots from mangrove trees extend into the intertidal and subtidal zone where they develop a rare function; hard underlying layers in an otherwise soft sediment environment (Nagelkerken *et al.,* 2008). These hard layers are used as attachment sites by tree-climbing crabs and other animals living more closely in the mud (Kon *et al.,* 2010). Mangrove roots become habitats for marine plants, algae, invertebrates and vertebrate animals. Mangrove swamps constitute a habitat for a wide variety of species and the swamp produces food for a large number of these (Nagelkerken *et al.,* 2008).

2.4 Field work

On a 1,1 km track through the mangrove 22 study sites where set with 50 meter intervals. The 22 study sites were marked with small tape pieces on the back of the railing of the boardwalk so no human could se the tape and remove it and to ensure that the observation was done on exactly the same site every time. At each study site, an area of 2 x 2 m was marked on both sides of the bridge and within this area the crab and the main environmental data were collected. The census of the number of crabs of the four different species, *S. serrata, U. vocans, S. mederi* and *P. bidens,* took place in the morning between 7 am – 12 pm. This time was chosen, as it is likely that higher density of crabs would be present in the cool start of the day. All sites were visited six times throughout the study period. The census of the different sites was carried out in a random order to get a variation of visiting times between sites. The number of crabs of each species was noted at each study site for 10 minutes; 5 minutes on each side of the bridge (Bibby *et al.,* 1998). Before the observation of 10 minutes started, 2 minutes were dedicated to standing still and being

silent because the crabs disappear when walking on the boardwalk. When for example a big group of people came by during the observation, the process started over because it was a large disruption.

On each study site, the dominating vegetation was noted, canopy shade estimated in %, and the depth of the water estimated. The names of present tree species were noted with help from species information signs present at the park describing the ecology of 10 different species in the park. The tree species were easy to determine using the information. For the vegetation data collection an area of 4 x 4 meters around the study site was used to increase the plant information. Shade of canopy was determined by estimating the percentage area of the ground that was in shade from the trees. To get a more reliable estimate of shade, two people independently estimated the shaded area and the results where compared. On the sites that exactly the same value was not observed, an average of the two observations was taken to get as correct value as possible. The shade estimation data was collected in the morning in order to be comparable to the inventory of crabs. In each study site the water depth varied between observations. Approximate values of water depth in 10 cm intervals were taken every observation (six times during the study period).

The factors used as human disturbance were distance to places that people, with high probability, would stop at. This was distance to information signs and distance to resting places such as benches. For these variables, distances from each study site to information signs and resting places along the walking trail were measured. How close the study site was to the road where many people/cars/motorbikes were moving and closeness to the river where there also was a lot of movement from boats but also a much higher water depth than inside the mangrove forest could also have an impact on the crab species. On each study site I noted if the road or river was present. This was done with the help of a map of the area (Fig. 4).

2.5 Statistical analyses

The vegetation data that were used in the analyzes was the most common vegetation and the second most common vegetation on the study sites. Of the four species of crabs one was not included in the analyses (*U. vocans*) because a very low number of observed individuals. A pairwise correlation was done for all environmental and disturbance variables. Correlations between environmental variables were r values ≤ 0.4 were used in the statistical analyses. A general linear model (GLM) with a poisson distribution was used to analyze the relationship between the environmental and disturbance variables with a total number of individuals of all species and total

number of individuals of the three different species. All statistical analyses were made in R (version 3.2.2, R Development Core Team 2015).

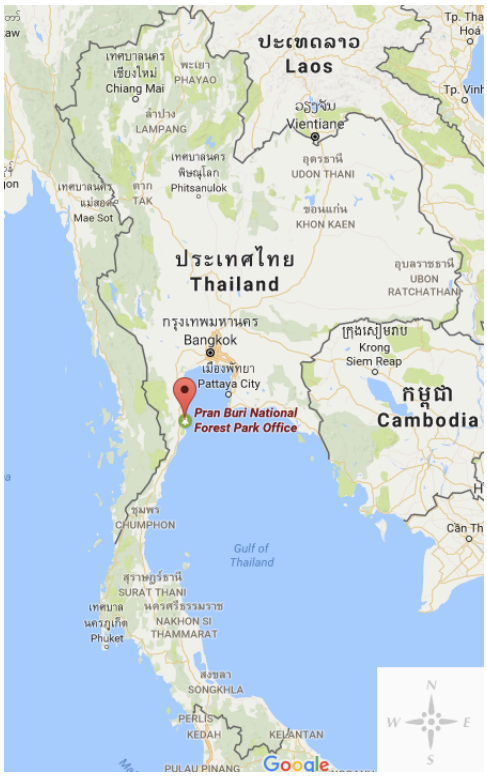

Figure 3. Map over Thailand and where the study was conducted, Pranburi Forest Park in the province of Prachuap Khiri Khan.
(Photo taken from google maps and edited by Johanna Rosenquist).

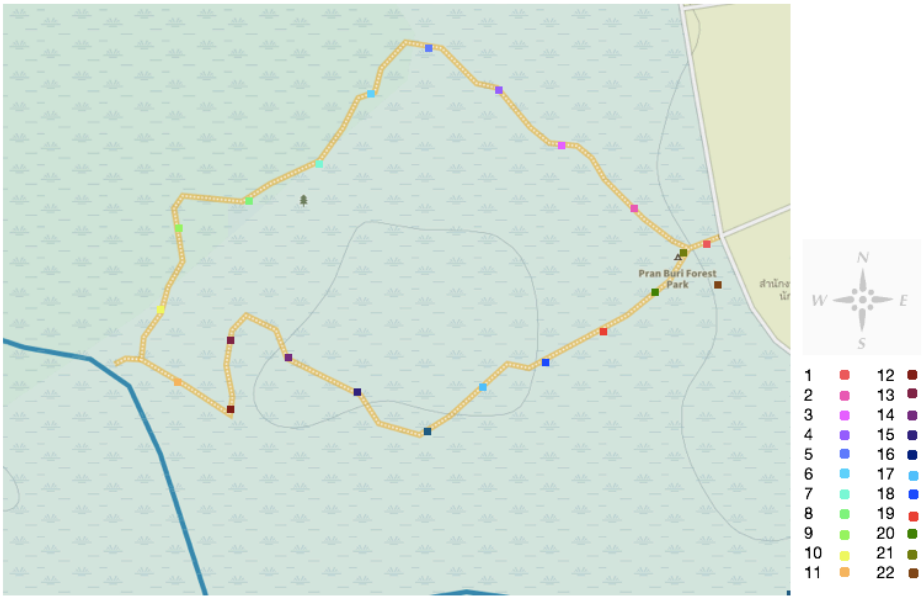

Figure 4. Map showing where the observation studies have been done, along a 1,1 km long elevated walking trail inside the mangrove forest. Dots in different colors indicate study sites 1-22. (Photo taken from Mapbox and edited by Johanna Rosenquist).

3 Results

3.1 General observations

In the study, a total of 902 individuals were found in total of the four species; 89 individuals of *S. serrata*, 2 individuals of *U. vocans*, 534 individuals of *S. mederi* and 277 individuals of *P. bidens.* The dominating plant species in all study sites was *Rhizophora apiculata* that was found on 17 of 22 sites. The second most common plant species were *Avicennia marina* and *Ceriops tagal* that were found on 6 of 22 sites. The canopy shade over the study sites was between 40 and 90% and the water depth between 0 and 12.5 cm. The river was present in 3 sites and the road in 7 sites. The distance to information signs was from 0 to 100 meters and distance to resting places was from 0 to 110 meters.

3.2 Environmental and disturbance factors

3.2.1 Environmental variables

With increasing water depth, I found more individuals of all species (see Table 1). Canopy shade was positively correlated to the total number of individuals of all species and abundance of *S. serrata*, *S. mederi* and *P. bidens* (Table 1).

Table 1. *Significance estimate value and standard error for GLM analyses testing the relationship between number and abundance of species and water depth and canopy shade.*

	Water depth Significance	Estimate	Std. Error	**Canopy shade** Significance	Estimate	Std. Error
Total number of individuals of all species	***	0,8006	0,1166	***	0,0218	0,0041
Abundance *of S. serrata*	**	1,2092	0,4417	*	0,0279	0,0132
Abundance of *S. mederi*	***	0,9413	0,1503	**	0,0156	0,0051
Abundance of *P. bidens*	*	0,4738	0,2173	***	0,0346	0,0085

· * = p<0,05 **= p<0,01 ***= p<0,001, ns = not significant.

R. apiculata is the most common plant species in the mangrove forest and was positively correlated with several of the different variables (Table 2). Where *R. apiculata* is present there is a higher total number of individuals of all species and also a higher value of individuals of *S. mederi*. The tree *C. tagal* was negatively correlated to crab presence and abundance. Where *C. tagal* was present less individuals of *S. mederi* and *P. bidens* were found and also a lower total number of individuals of all species. The tree *A. marina* showed a negatively correlation for total number of individuals of all species, abundance of *S. serrata*, abundance of *S. mederi* and abundance of *P. bidens.* Where *A. marina* is present fewer individuals of *S. serrata*, *S. mederi* and *P. bidens* were found and also a lower total number of individuals of all species.

Table 2. *Significance estimate value and standard error for GLM analyses testing the relationship between number and abundance of species and the plant species (R. apiculata, C. tagal and A. marina)*

	R. apiculata Significance	Estimate	Std. Error	***C.tagal*** Significance	Estimate	Std. Error	***A. marina*** Significance	Estimate	Std. Error
Total number of individuals of all species	***	3,3579	0,4638	***	-1,0635	0,1451	***	-0,5567	0,1171
Abundance of *S. serrata*	ns	-	-	ns	-	-	*	-0,9961	0,4026
Abundance of *S. mederi*	***	2,8513	0,5237	***	-0,7616	0,1750	*	-0,3780	0,1484
Abundance of *P. bidens*	ns	-	-	***	-2,111	0,305	***	-0,8631	0,0,2337

* = p<0,05 **= p<0,01 ***= p<0,001, ns = not significant.

3.2.2 Human disturbance

The closer to an information sign the less total number of individuals of all crab species and individuals of *P. bidens* were found (Table 3). Distance to human resting places was significantly negative for all crabs except for *S. serrata*. For all three disturbance variables the correlation was negative which indicates that the closer to resting places the less total number of individuals of all species and less individuals of *S. mederi* and *P. bidens* where present.

Table 3. *Significance estimate value and standard error for GLM analyses testing the relationship between number and abundance of species and disturbance variables; distance to information signs and distance to human resting places.*

	Distance info. sign Significance	Estimate	Std. Error	**Distance resting places** Significance	Estimate	Std. Error
Total number of individuals of all species	**	-0,0064	0,0021	***	-0,0076	0,0015
Abundance of *S. serrata*	ns	-	-	ns	ns	ns
Abundance of *S. mederi*	ns	-	-	**	-0,0054	0,0020
Abundance of *P. bidens*	***	-0,0140	0,0041	***	-0,0109	0,0028

* = p<0,05 **= p<0,01 ***= p<0,001, ns = not significant

The disturbance variable closeness to the road was negatively correlated to all the species (Table 3). The closer to the road the less individuals in total and of all the three species was found. *S. serrata* also showed a negative correlation to closeness to the river, the closer to the river the less individuals of this species. So *S. serrata* is truly most found at the study sites between the road and the river. *S. mederi* have a positive relationship with the presence of a river, so the closer to the river the more individuals were found.

Table 4. *Significance estimate value and standard error for GLM analyses testing the relationship between number and abundance of species and disturbance variables; closeness to road and river.*

	Road Significance	Estimate	Std. Error	**River** Significance	Estimate	Std. Error
Total number of individuals of all species	***	-0,8262	0,1148	ns	-	-
Abundance *of S. serrata*	***	-2,0692	0,4295	*	-1,1743	0,5457
Abundance of *S. mederi*	***	-0,6591	0,1481	**	0,5558	0,1698
Abundance of *P. bidens*	***	-0,8208	0,2186	ns	-	-

* = p<0,05 **= p<0,01 ***= p<0,001, ns = not significant

4 Discussion

From my results it shows that some species have a higher abundance than others. The sesarmids crabs *S. mederi* and *P. bidens* have a higher abundance than *S. serrata* and *U. vocans*. This might be because the sesarmids crabs are more tolerant to diverse conditions than the other species, or that the other species is more burrowed in to the mud and therefore not as easy to spot. Other studies have show that mud crabs, as *S. serrata*, are primarily feeding at night and are burrowed in the mud during the day (Hill, 1976) and this could be a reason for a lower abundance of *S. serrata* compared to the sesarmids crabs. This study is done during a short period of time in one of the seasons in Thailand, this can effect the result, though this study does not show if there are any seasonal effects on the appearance of crabs. It could be that some species is more common to see in other seasons of the year, but as mentioned, this is not investigated in this study.

4.1 Environmental variables

The environmental variables that were analyzed in this study were water depth, canopy shade, dominant vegetation (*R. apiculata*, *C. tagal* and *A. marina)*. Closeness to river can be used as both human disturbance factor and also an environmental variable because the river has a higher water depth than inside the mangrove forest. All the variables correlated with either total number of individuals of all species or the presence of the species *S. serrata*, *S. mederi* and *P. bidens*. For number of species per study site, no significant correlations were found for any of the variables. The different environmental variables are discussed in subheadings below.

4.1.1 Water depth

The results from Matsui et al., (2014) indicates that lower water depth result in more algae bloom. That should provide a food source for crabs in mangrove forest and therefore could increase individuals of species in low waters. The results from this study shows instead that with increasing water depth more individuals of all species were found. On the study sites where there was no water at all there was not any species or individuals observed. Previous studies have found that *S. serrata* has been

shown to be dependent on water depth (FAO, 2011) and this is also seen in my study. That connection with water depth in this species should be further studied since the total number of individuals of *S. serrata* on this study was quite low compared to the other species, only 89 individuals were observed throughout the study. It is possible that this relationship shows a higher number of many crab species in the mangrove forest during the rainy season compared to this hot and dry season.

4.1.2 Canopy shade

Previous studies have shown that canopy shade has a positive correlation to the presence of crab species as it generates a steady physical environment with controlled variations in temperature etc. (Kon *et al.,* 2010). In a later study Kon et al., (2011) have shown that with a high percentage of canopy shade, fewer individuals of crabs were found. Thus, the species richness was the highest in gaps from canopy. This might be because shade from canopy reduces benthic microalgae production, which in some species is a food source (Kon *et al.,* 2011). The sesarmids food source is leaf litter and the presence of these species does not depend on a high percentage of shade from canopy and therefore not on how much leaf litter that comes from the canopy (Diele *et al.,* 2012). My results reinforce earlier results as it shows that canopy shade and the total number of individuals of all species are correlated. With less shade from canopy the less individuals of all species were found. This also applies for the three different species. For conservation management in the park it is therefore important to not cut down trees if the purpose is to maintain a high biodiversity.

4.1.3 Vegetation

The occurrence and abundance of crab species in mangrove forests has been shown to be correlated with vegetation (Bandibas *et al.,* 2016). A greater number of individuals have been found of *S. mederi* and *P. bidens* in forest with *R. apiculata*, as this is a food source for these species of crab (Diele *et al.,* 2012). In Pranburi Forest Park, *R. apiculata* was the most common vegetation and it was also the vegetation that positively correlated with total number of individuals of all species and *S. mederi*. Where *R. apiculata* were present there was a bigger chance of finding more individuals of *S. mederi.* The results from this study resemble to the earlier studies except for the occurrence of *P. bidens* that was not significant with *R. apiculata.*

The second most common vegetation was *C. tagal* and *A. marina* and showed a negative correlation with crab species presence and abundance. This can be because *C. tagal* and *A. marina* not is a food source for any of the species that lives in this mangrove forest. Also what could have affected the lack of individuals near this

vegetation could have been that this vegetation was present at a lower water depth and as shown increasing water depth entails more species and individuals.

This result shows that a greater number of individuals have been found where *R. apiculata* grows and with absence of *C. tagal* and *A. marina*, therefore I think that the park management should plant *R. apiculata* when reforestation to favor the crab species.

4.2 Human disturbance

4.2.1 Closeness to information signs and human resting places

The variables used as human disturbance in this study was closeness to information signs and closeness to resting places as benches, and closeness to river and road. These variables have not been used previously in studies on crabs, but there are studies that shows that boardwalks in mangrove forest can have a negative impact on species richness and individuals of crabs. Human disturbance that comes from boardwalks is e.g. noise when using the boardwalks (Kelaher *et al.,* 1998). In this study I looked closer on the human disturbance to see if these affect the crab species in mangrove forest. A disturbance factor from human on boardwalks could be noise when using the boardwalk. What I believed was that it should be a negative correlation close to both information signs and resting places as more people stop at these places which leads to local noise. From my results I can see that the distance to information signs do significantly affect species numbers negatively. The closer to to an information sign the less individuals of all species together and *P. bidens* were found. Distance to resting places also showed a negative correlation for crab species; total number of individuals of all species and the species *S. mederi* and *P. bidens* were negatively correlated by closeness to resting places. The closer to resting places the less individuals in total and of *S. mederi* and *P. bidens* were present. To measure these disturbance factors I measured along the walking trail, it could have been a different result if I would have measured the "as the bird flies" though the noises travels trough the forest and may have closer way to travel to the different information signs and resting places.

The results show that the closer to information signs and resting places the fewer individuals are found, what the park management can do to favor the crab species is to not put up more information signs or benches that can disturb the species. They

could also set up opening hours to enter the park (it is now open around the clock) to reduce visitors and therefore reduce the disturbance variables.

4.2.2 Closeness to river and road

These variables correlated negatively to all the species. *S. serrata* showed a negative correlation for the road, the closer to the road the less individuals of *S. serrata* were found. *S. serrata* also had a negative correlation for the river, which make me believe that this is a very sensitive species. The distance to the river was positively correlated with *S. mederi*, according to this, the presence of *S. mederi* was greater near the river. I think this may indicate that *S. mederi* thrives in an environment where it is a bit deeper water and when water moves more, as it also closer to the open ocean. Maybe it could be so that *S. mederi* likes a higher salinity in the water and that it is that closer to the river and therefore closer to the ocean. To know that more definitely this study could be done with several variables such as salinity in the water.

5 Conclusion

When I visited Pranburi Forest Park for the first time I saw several information signs with different crab and a lot of text about the species (unfortunately only in Thai). I became curious about the crabs and why it was so much information about them through the park. There were also a lot of signs describing different tree species along the walking trail and there was always a sign where there was a change of tree species. I started to wonder if the tree species and crab species hade some sort of impact of each other. In my study I wanted to see if the different species was correlated to different variables, both environmental and human disturbance variables. I found that the crab species were correlated to the different variables in several different ways. In the sections underneath I have compiled witch variables that has an impact on the three different species. To my disappointment I did not get to see the fiddler crab *U. vocans*.

5.1 Abundance of *Scylla serrata*

The abundance of *S. serrata* depends on environmental variables such as water depth, canopy shade and present of tree species. The more individuals of *S. serrata* is found where is a high water depth, a high percentage of canopy shade, where *A. marina* is not present. *S. serrata* also depends on human disturbance factors such as closeness to road and river. The closer to the road and river the less species were found. Human disturbance such as distance to information signs and distance to resting places does not affect *S. serrata*.

5.2 Abundance of *Sesarma mederi*

The presence of *S. mederi* depends on both environmental variables and human disturbance. To find more individuals of *S. mederi* it has to be a high water depth, a

high percentage of canopy shade, *R. apiculata* has to be present, but far away from *C. tagal* and *A. marina*. Closer to the river it is most likely to find more individuals and closer to resting places and the road you find less individuals.

5.3 Abundance of *Perisesarma bidens*

The presence of *P. bidens* also depends on both environmental variables and human disturbance factors. Where it is a high water depth and a high percentage of canopy shade and far away from *C. tagal* and *A. marina*, also far away from the road, information signs and resting places you can find more individuals of *P. bidens*.

5.4 Conservation management

By eating or by burial activities sesarmids crabs remove up to 30-90 % of the yearly litter fall (Kristensen, 2008). By removing the litter fall the crabs help the mangrove ecosystem to stay healthy and to keep a high biodiversity. What is done today to keep the mangrove forest in Pranburi Forest Park alive and healthy is reforesting, where organizations, such as Chiva-som and Preserve Hua Hin group, plant new trees in the park. These organizations help young students to gain more knowledge of the mangrove ecosystem and to learn about the symbiotic relationship between the trees and animals in the park (Chiva-som, 2012). This is a very important part of the conservation of mangrove forests because people need to understand the stability and fragility of the mangrove ecosystem.

One thing that is done to help preserve the crab species that is shown on information signs in the park, is to reintroduce individuals of different crab species, mostly *S. serrata,* in the mangrove forest. I do not know exactly why they release individuals of crabs in the mangrove forest, if it is because there are believed to be few and they want a higher abundance to keep the mangrove forest alive and healthy. I think the intention with this work is good, but in this study I have not seen a lot of this species compared to the sesarmids crabs.

I think it is very good that there is a walking trail through the mangrove forest that can help educate people about animals and trees in the forest. A very big part of the mangrove forest is not reachable for humans. This can help preserve the mangrove forest at large, by educating people. A part of the forest must not be disturbed by humans, except from reforestation activities, that for example Chiva-som and Preserve Hua Hin group are doing.

5.5 Further work

To continue with this study and elaborate it, there are some variables to use in addition to those in this study. These variables could be to measure pH and salinity in the water, as the crab species has show to be affected by this in previous studies (FAO, 2011). The observation in this study is only done in the morning and do not show if there are difference during the time of day. This could therefore be done in the afternoon and in the evening or night to determine when there is highest abundance of the different species. As mentioned in the discussion this study does not show if there are any seasonal difference on the appearance of crab species and could also be done. What would be interesting to investigate is also how the results of this study would look if the observation had been done further away from the boardwalk, deeper in the mangrove forest. This was not possible at the time, as it was forbidden to leave the boardwalk and therefore the study sites were set to 2 x 2 meters, it was hard to establish the movements of the crab species when using this size of study sites. If it would be possible do have the study sites deeper in the mangrove forest and therefore bigger, the movement of the crab species could easier be observed. One more thing to elaborate is the canopy shade, in this study it is focused on the shade and if there are more individuals where there are more sun or shade. The result showed that there are more individuals where it is more shadow from the canopy. It would be interesting to know more about if the trees are important as shelter from predators and if more shade means more roots to seek shelter under and therefore are more individuals. To elaborate this study even more a variable that can be used is if there are any biotic interaction between the crab species or between the different crabs and other animals in the mangrove forest, such as birds or fishes.

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