Spring 2021

An Assessment of Terrestrial Decapoda Diversity Across Three Ecological Zones in Mida Creek, Kenya

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SIT Study Abroad

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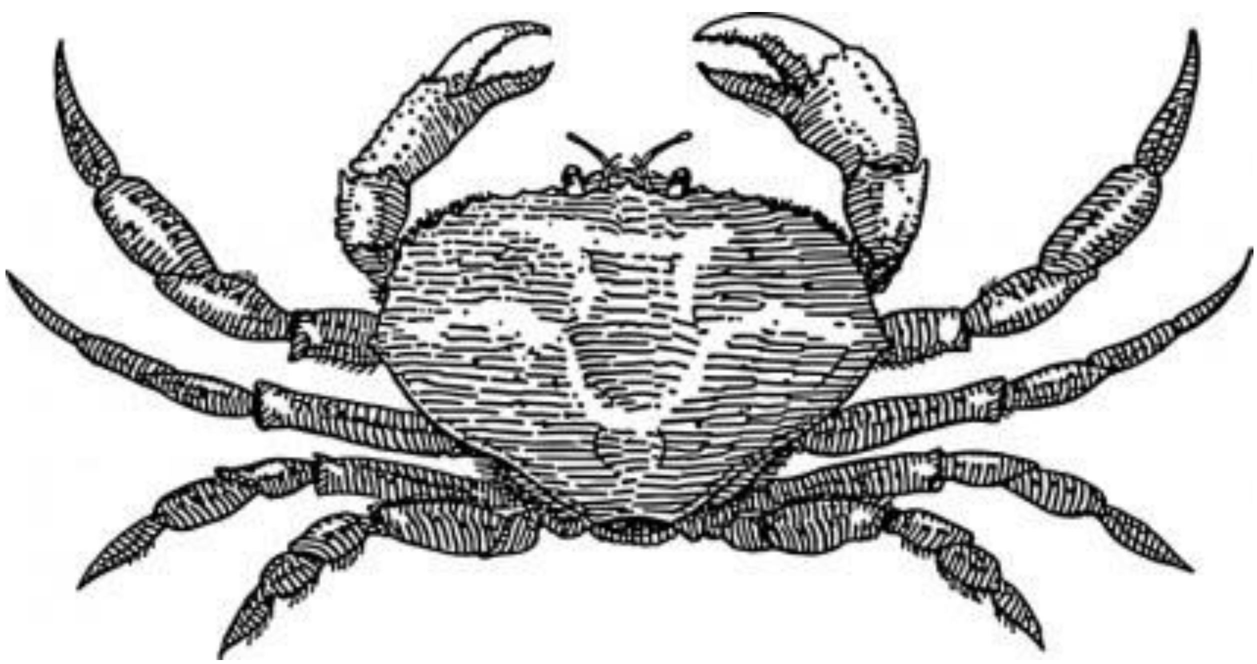
TZR: Ecology, Wildlife, & Natural Resource Management
SIT Tanzania and Kenya Spring 2021



Acknowledgements

Many great people are to thank for seeing our SIT class through this hectic semester. First and foremost, I would like to thank our wonderful SIT staff back in Arusha Tanzania for all the countless hours of work they put in behind the scenes both day and night. To Dr. Oliver Nyakunga (Mama O) our academic advisor, without you our program would never have made it out of Tanzania. To Oscar Paschal (Mbogo) our activities coordinator who provided endless support and knowledge throughout all aspects of the program. To kaka Kaiza Kaganzi our wildlife expert whose expertise in both wildlife analysis was invaluable. To mama Juni for always making sure we got to where we needed to go. Secondly, the SIT staff in Kenya was helpful during the transition and made our ISPs possible regardless of the short time given. Steve Wandiga and Miltone were great resources during our time in Kilifi. I would also like to thank Dr. Charles and Dr. Rose for their assistance and furtherment of our academia while in Kenya. I would also like to thank all of our gracious hosts both in Tanzania as well as Kenya including Klub Afriko, Carona House, Glorias House, and Makuti Villas. My study would not have been possible without the assistance of my guide Hassan Kombo at Mida Creek, Kenya. Not only did he help select my study site, but he was invaluable at identifying plants and crab species throughout the forest. Finally, I would like to thank all the support I received back home from SIT staff in the states, my home institution Hope College, and my own friends and family. Without their support, I would not be here in the first place.

Abstract

Mangroves make up one of the most effective natural remedies at combating climate change today. They represent great commercial interest worldwide and yet, are being degraded at an unsustainable rate. If successful mangrove conservation plans are to be implemented for our posterity, mangrove ecosystems need to be better understood at the community level. Mangrove crabs make up the most diverse and populace mangrove inhabitants. They are classified as ecosystem engineers and their potential for being used as bioindicators makes them integral to assessing mangrove health. Yet, their diversity and distribution patterns are not well understood. The aim of this study was to survey general terrestrial *Decapoda* diversity and distribution patterns within a mangrove forest habitat. Surveys were carried out at Mida Creek, Kenya 3*19’27 S, 39*57’49 E. Quadrat sampling was utilized across three distinct levels of zonation driven by water access and expressed by mangrove species type. One-way Anova tests yielded significant results for crab density across all three zones as well as species richness between two zones suggesting zone specific crab distribution. No correlation was found between either mangrove density or canopy cover as they pertained to crab density. Knowing crabs are tied to specific zones while not being directly influenced by mangrove species suggests other biotic or abiotic factors are at play with determining species gradients.

Keywords: Mangroves, Mangrove Crab, Mida Creek, Kenya, Zonation, Distribution Patterns, Correlation

Abbreviations and Acronyms:

NMEMP	National Mangrove Ecosystem Management Plan
MTC	Mangrove Technical Committee
SIT	School for International Training
NIH	National Institute of Health
ISP	Independent Study Project

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1. Introduction

1.1 Background Information:

Mangroves are one of the most important keystone flora on the planet providing habitats for thousands of species worldwide. Their ecosystems are some of the most biodiverse of any ecosystem with over 70 species spanning 136 countries across different niches. Mangroves also provide crucial protection and preservation of the coastlines from ocean erosion. They store upwards of 10 times the amount of carbon per hectare than terrestrial forests making them effective equalizers of a compromised atmosphere. This, coupled with their innate ability to filter water and trap sediments otherwise harmful to reefs, necessitates their conservation in the critical battle against climate change (Ecoviva, 2016; "Share the Facts About Mangroves," 2021). On top of their environmental importance, mangroves have economic incentives to conserve them. Recent estimates places their annual value at $194,000 USD per hectare (Ecoviva, 2016). Yet, regardless of their global importance, mangrove ecosystems continue to be degraded at an unsustainable rate. From 1980 to 2003, mangrove cover worldwide declined from an estimated 19.8 million hectares in 1980, to 15 million hectares in 2003, a 25% global reduction (Wilkie Mette & Fortuna Serena, 2003). Should this trend continue, there will be no mangroves left on the planet by the year 2072.

To date, mangrove forests in Kenya cover 61,271 ha accounting for 3% of all natural forests and approximately 1% of the national land area. Out of the 70 species spanning the planet, nine are represented within the Kenyan ecosystem with *Rhizophora mucronata* and C*eriops tagal* being the most common. Mangrove forests in Kenya have not been immune to the worldwide decline of their species. Local threats include increased population, weak governance, inadequate awareness of the true value of mangrove ecosystems, high levels of poverty, lack of alternative livelihoods, and inadequate management prescriptions (J. et al., 2017). In order to combat the loss of mangroves within Kenya, the Mangrove Technical Committee (MTC) oversaw the creation and implementation of a National Mangrove Ecosystem Management Plan (NMEMP) spanning from 2017 – 2027 (J. et al., 2017). Within the plan, MTC cites the importance of continued ecosystem monitoring not only to evaluate the success of NMEMP, but to better understand the ecosystem for the development of future plans as well. This study seeks to be one such study from which future conservation plans can draw from.

Problem Statement:

Despite the comprehensiveness of NMEMP, not once does it mention crabs. Out of all the invertebrates that call the mangrove ecosystem home, crabs are the most abundant (“Mangrove Life – South Florida Aquatic Environments,” n.d.). Both sesarmid (Grapsidae) and fiddler crabs (Ocypodidae), which are the most common within mangroves, are classified as ecosystem engineers (Kristensen, 2008). Classifying crabs as ecosystem engineers, coupled with their potential use as an indicator species, makes them critical for ecosystem health and yet, their distribution patterns are not well understood (Geist et al., 2012; Jigneshkumar et al., 2014). This study seeks to assess crab diversity as it pertains to forest zone. Furthermore, collaborative research with a mangrove scientist at the same site offers opportunity for comparison of crab distribution with mangrove density and cover. Better understanding of crab distribution within mangrove ecosystems will allow for a more effective implementation of future conservation plans for both mangrove and crab species alike.

Literature Review:

Zonation patterns within mangrove forests have long been investigated (Graham, 1929; Kokwaro, 1985; Van Speybroeck, 1992). However, a vast majority of these studies are focused exclusively on the distribution of the flora within mangrove forest ecosystems. Remarkably little is published on the distribution of the fauna. Out of all the fauna present within mangrove ecosystems, decapods have been reported worldwide to affect mangrove distribution the most. They do this by affecting recruitment as a result of their feeding habits (Osborne & Smith, 1990; Thomas J. Smith, 1987). In Kenya specifically, species of decapods have been documented feeding on mangrove propagules (Dahdouh-Guebas et al., 2002). The drastic impacts decapods have on the mangroves necessitates further studies of their distribution within the mangrove ecosystems.

The ecological importance of crabs within a mangrove forest ecosystem is well documented; they increase key nutrients in the soil such as soil sulfide and ammonium leading to higher mangrove productivity (Thomas J. Smith, Boto, Frusher, & Giddins, 1991). While both sesarmid and fiddler crabs are ecosystem engineers, their foraging patterns differ. The sesarmid crabs form a fine organic material which is ideal for microbial colonization and macrofaunal detritivores. The fiddler crabs do the opposite by removing organic carbon from the surface which in turn has a negative effect on decomposers and other detritus consuming organisms (Kristensen, 2008). Their differing foraging patterns results in strict species gradients based on diet, water coverage, and type of food available (Icely & Jones, 1978).

At Mida Creek, Kenya, gradients are observed within the mangroves. Three distinct patterns of zonation occur at the site being driven largely by access to water and soil type. Zone three is closest to the water's edge, zone one is furthest from the water, and zone two is in between. It is likely that there is correlation between crab distribution and mangrove zonation. A preliminary study conducted in 2002 conducted at Mida Creek found correlation between crab and mangrove species distribution due to a variety of both biotic and abiotic factors (Dahdouh-

Guebas et al., 2002). My study seeks to build upon the Dahdouh-Guebas study as well as others to build a more complete picture of terrestrial crab distribution patterns in relation to mangrove forest zones. More specifically, this study seeks to understand how mangroves specifically affect the location of terrestrial *Decapoda* throughout the mangrove forest at Mida Creek, Kenya.

Objectives:

General Objective:

To assess the diversity of terrestrial Decapoda (crabs) across three mangrove zones at Mida Creek, Kenya.

Specific Objectives:

i. To assess crab species richness and abundance at Mida Creek Kenya.

ii. To assess the association between crab density in relation to mangrove density.

*Hypotheses***:**

i. *Alt:* Crab diversity will be highest in zone two due to zone two exhibiting the highest level of mangrove diversity.

   Null: There will be no significant difference in crab diversity across the three zones

ii. *Alt:* Crab and mangrove density will be positively correlated due to many crab species relying on mangroves directly for food

   Null: There will be no correlation between mangrove and crab density

Methodology

Ethical Considerations:

All ethical guidelines put forth by the National Institute of Health (NIH) as well as the SIT: ISP Internship Statement of Ethics were adhered to throughout the duration of this study (National Institute of Health, 2016). From the conception of the study, every aspect was reviewed by an advisory board with long histories of research expertise. All methodology and supplies needed were vetted through local advisors. When in the field, intentions were conveyed clearly to those in employment at Mida Creek. Careful steps were taken to ensure low to no environmental footprint was left behind. All crabs sampled were handles with care. Precautions were taken to ensure interactions with locals on site were conducted in a respectful manor. Drinks were purchased daily from the local crab shack daily to support the local community and foster human relations. Permission was obtained from our guide Hassan Komob to both site him and his contributions in our study, as well at utilize pictures of him taken throughout.

Study Site Description:

Mida Creek is located on the north-east Kenyan coast at 3*19’27 S, 39*57’49 E (Fig 1). The area is most known for its valuable mangrove forest which spans an estimated 1657.8 ha of the 31.6 km^2 total area (Alemayehu, et al., 2014; Owuor et al., 2017). Mida Creek was gazetted as a national marine reserve in 1968 (Kairo et al., 2002) and designated as a UNESCO Biosphere reserve in 1979 (“UNESCO,” 1979). Of the nine species of mangroves found within Kenya, seven are represented at the study site. Species found at the site include *Rhizophora mucronata, Ceriops tagal, Avicennia marina, Sonneratia alba, Xylocarpus granatum, Bruguiera gymnorrhiza and Lumnitzera racemosa* (Alemayehu et al., 2014). There are seven settlements consisting of approximately 6821 households directly adjacent to Mida Creek; many of those households rely on fishing for their livelihoods (O'Neill, 2021). Destructive fishing habits rank among the most harmful for mangrove recruitment (Geist et al., 2012).

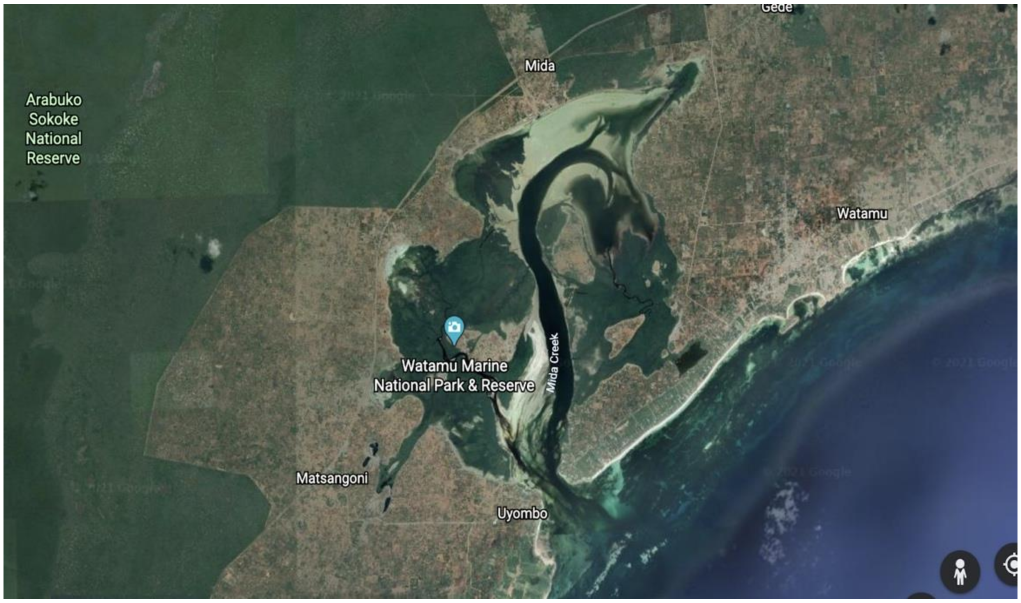

Fig 1. Mida Creek, Kenya. Photograph attained using Google Earth version 7.3 run on macOS 11.1 ("Google Earth," n.d.).

The mangrove forest at Mida Creek exhibits three areas of zonation (Fig 2). The first zone consists primarily of white mangroves (*Avicennia marina*), the second zone primarily red mangroves (*Rhizophora mucronata*), black mangroves (*Bruguiera gymnorrhiza*), and yellow mangroves (*Ceriops tagal*), and the third zone primarily of apple mangroves (*Sonneratia alba*). It is these distinct patterns of zonation that make Mida Creek an ideal study site for assessing mangrove crab distribution patterns.

Fig 2. Ariel photograph of the three forest zones exhibited at Mida Creek, Kenya. Photograph attained using Google Earth version 7.3 run on macOS 11.1 ("Google Earth," n.d.).

Data Collection:

Three days were spent collecting data at Mida Creek in Kenya starting Tuesday April 13th through Thursday April 15th with an additional preceding prep day led by our guide Hassan on Monday April 12th. Mida Creek was selected as the site of study due to its distinct mangrove forest zones. Transportation to and from the study site was provided by SIT staff. Location of arrival was the parking lot of the crab shack run by the local Mida Creek Conservation Community located at -3˚19'32" S, 39˚57'55" E. The time of arrival varied due to the study requiring a low tide, as well as our guide Hassan's availability. Once on the ground at Mida Creek, metadata including date, time, temperature, wind speed, precipitation, cloud cover percentage, humidity, and tide direction was recorded (Appendix B). The following study was conducted alongside fellow researcher Davis-Oakes who was studying mangroves at the same site. In the interest of collaborative results, common transects and quadrats were utilized throughout.

Research Methods:

One transect was placed within each of the three forest zones (Fig 3). Exact transect placement was decided upon arrival to the forest with factors such as sampling viability, distance from other zones, and Hassan's recommendations being considered. Transects were attempted to be kept straight but given the density of zone two and traits of zone three, this was not always be possible. Given that each transect was kept to a length of 200 meters, the failure to keep straight transects is negligible. Along each transect, ten, one square meter crab sampling quadrats were systematically placed every twenty meters. To eliminate bias, the side of the transect on which the quadrat is placed was decided via coin flip with heads representing the right side of the transect, and tails representing the left side. The one square meter crab quadrats were then surrounded by a five square meter mangrove quadrat. The mangrove quadrat spanned 2½ meters on either side of the midpoint of the crab quadrat, and then five meters out on whatever side was sampled as dedicated by the coin flip. Both quadrats utilized the transect as one of their four sides. GPS coordinates were recorded at both the start and finish of the transects.

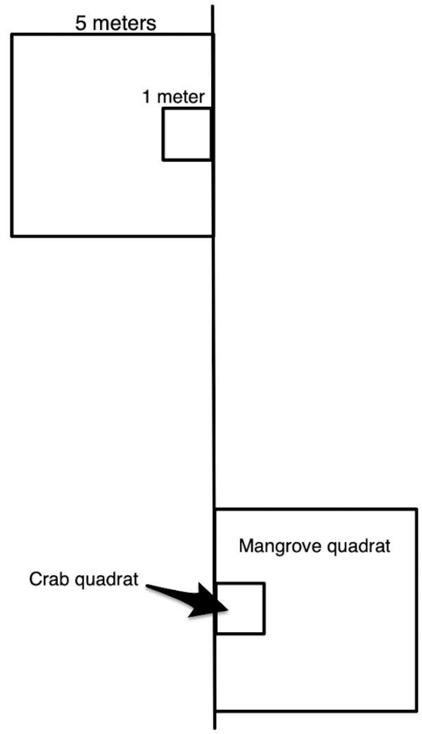

Fig 3. Sample Transect Layout. Diagram drawn using Skitch version 2.8 run on macOS 11.1.

Due to the Western bank of Mida Creek not containing enough of the zone three ecosystem, a boat was utilized to carry us across to an adjacent island south-east of our original study site where zone three could be better observed (Fig 4). The island was still within the boundaries of the Mida Creek protected area.

Fig 4. Zone three lies approximately 250 meters south-east of the zone two study site. Photograph attained using Google Earth version 7.3 run on macOS 11.1 ("Google Earth," n.d.).

Crab Quadrat Sampling Method:

Once the quadrats were placed, the first five minutes was spent recording metadata such as number of burrows present, canopy coverage percentage, number of invertebrates excluding crabs, and whether water is present within the area. Recorded meta data ended up being outside the scope of this study. This time also allowed the ecosystem to recover from the shock of my presence. Ideally, more time would have been allowed for ecosystem recovery. The constraint to three days of data collection necessitated shorter observation periods. The proceeding five minutes were spent recording every type of crab species present within the quadrat, or that crossed into the quadrat while sampling. The help of Hassan was enlisted to ensure accurate identification. At the end of the three days of data collection, the data was compiled and sorted for further data analysis.

Throughout the four days spent at Mida Creek, all terrestrial crab species encountered were photographed and identified. All crab species were then compiled into an identification chart to better help with identification in the field. This completed identification chart can be found in appendix A. All terrestrial crabs encountered were recorded regardless of whether they were found along the transect.

Collection Timeline:

Day one: Day one was spent surveying our site. A five-mile survey of our study site was conducted on foot. All three mangrove zonation patterns were investigated, and study sites were proposed. All terrestrial crab species were identified and compiled in an identification chart to help with identification during data collection. Following the site survey, zonation characteristics were logged in a research journal and methodology was revised.

Day two: Transect one started at -3˚32'91" S, 39°96'48" E and headed 240˚ SE for 200 meters ending at -3˚32'83" S, 39°96'26" E. Ten total quadrats were sampled systematically every twenty meters. Data collection took place between 9:12 am and 11:17 am.

Day three: Transect two started at -3˚32'83" S, 39°96'28" E and headed 160˚ SE for 200 meters ending at -3˚33'37" S, 39°97'48" E. Ten total quadrats were sampled systematically every twenty meters. Data collection took place between 9:56 am and 12:18 am.

Day four: Transect three started at -3˚35'02" S, 39°96'78" E and ended at -3˚35'17" S, 39°96'88" E. No direction was kept due to the winding nature of zone three. Ten total quadrats were sampled systematically every twenty meters. Data collection took place between 9:53 am and 1:26 pm.

Results

Objective 1:

Species Richness:

The total numbers of species identified across the four days was fourteen, thirteen of which were terrestrial *Brachyura*. Identified species including nine species from the *Ocypodidae* family, one species from the *Ocypodidae* family, one species from the *Sesarmidae* family, one species from the *Gecarcinidae* family, and one from the *Calappidae* family. A complete list of the crab species categorized along with their scientific names can be found in Appendix A. Species richness was 14 across the three zones. Not all species were identified in those four days were found within the three transects. Species richness for transect one was five, transect two was two, and transect three was six. Total species richness *sampled* across the three zones is seven (fig 5). Species richness counts excluded baby fiddlers which are impossible to identify until they reach a certain number of molts.

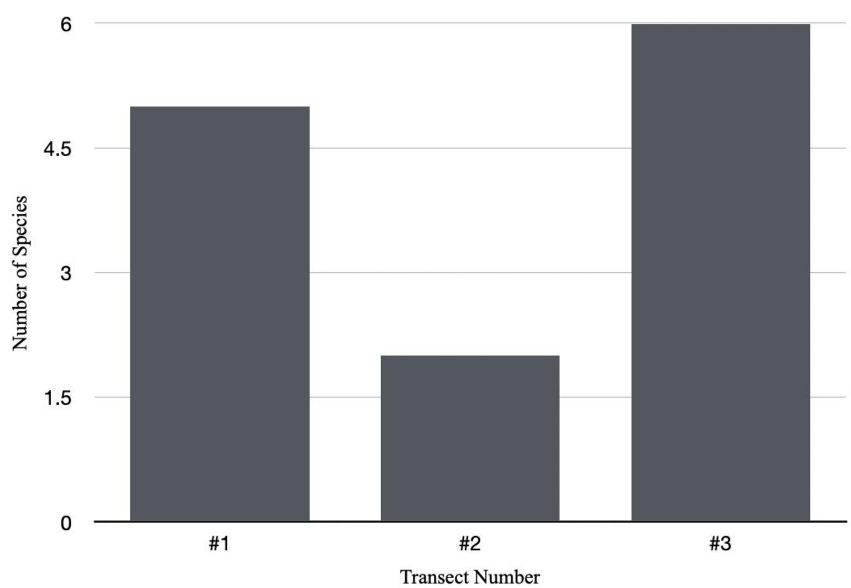

Fig 5. Number of crab species identified along each transect across three zones at Mida Creek, Kenya. Data collected and compiled by Reese Yount.

With species richness seemingly being skewed across the three different zones, tests for variance were conducted for significance. Data was compiled to represent the number of species recorded within each quadrat. Following completion of a one-way ANOVA test for variance, zones one through three were found to significantly differ from one another in species abundance ($F_{2,27} = 3.54$; $p = 0.043$; $\alpha = 0.05$).

A post hoc test was conducted to determine where the significance lie. Three Fishers found that Zone two differed significantly from zone one ($F = 15.25$; $Fc = 3.17$; $\alpha = 0.05$;), and zone three ($F = 7.25$; $Fc = 3.17$; $\alpha = 0.05$) at the species richness level. Zones two and three were not significantly different ($F = 2.1$; $Fc = 3.17$; $\alpha = 0.05$).

Species Density:

A total of 354 individuals were sampled across the three-day period. Species density was highest in zone one with 210 sampled individuals, followed by zone three with 79 individuals, and zone two with 65 individuals (fig 6). The quadrat with the highest density was found in zone one quadrat nine with 68 individuals per m^2. Low density quadrats harboring zero individuals were recorded twice during zone one, and once during zone three (Appendix B).

The genus of crabs *Uca* (fiddler crabs) dominated zone one boasting 179 across three species (fig 6). Zone two was made up of almost exclusively *Neosarmatium meinerti* representing 60 of the 65 individuals sampled (Fig 6). Zone three was dominated by the *Uca* having sampled 55 individuals across four sub species (fig 6). Zone three was the only zone in which the soldier crab (*Dotilla fenestrata*) was present.

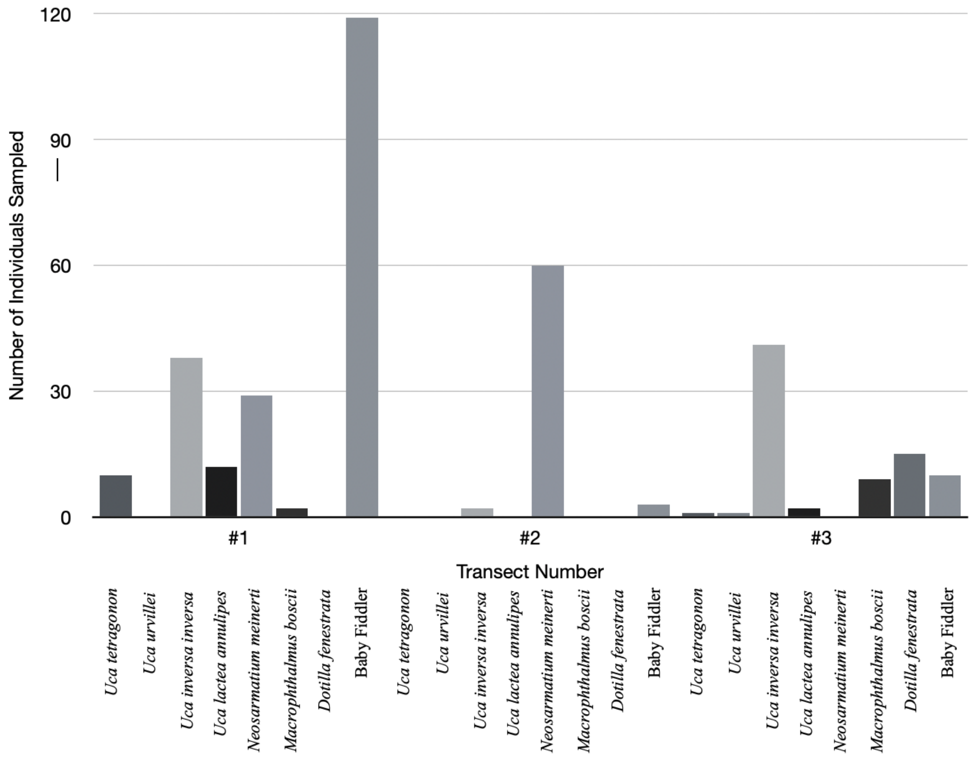

Fig 6. Number of individual crabs recorded at the species level spanning three zones. Data collected and compiled by Reese Yount.

With drastic disparities in crab counts spanning the three zones, a one-way ANOVA test for variance was conducted. Crab counts were grouped together based on total sampled regardless of species. Following completion of the test, all three zones were found to significantly differ from one another in species abundance ($F_{2,27} = 3.70$; $p = 0.037$; $\alpha = 0.05$).

Three Fishers tests were conducted to determine where the significance lie. All three zones had high enough F-values to vary significantly from one another in the number of individuals sampled along their respective transects. Zone one varied from zone three ($F = 33.7$; $Fc = 3.17$; $\alpha = 0.05$). Zone two varied from zone three ($F = 4.64$; $Fc = 3.17$; $\alpha = 0.05$). Zone one varied from zone three ($F = 7.24$; $Fc = 3.17$; $\alpha = 0.05$).

Objective 2:

Crab Density as it Relates to Mangrove Density:

To better understand crab zonation patterns at Mida Creek, a collaborative study using data from fellow student Gilleyanne Davis-Oakes, who was studying Mangroves on site, was conducted. A Pearson's Correlation Coefficient was run comparing crab density and mangrove density within each quadrat. A weak trend was detected with the number of crabs declining in an adverse relationship with mangrove density. However, the r-value received was too low to be significant (α = 0.05; df = n-2; r = -0.13).

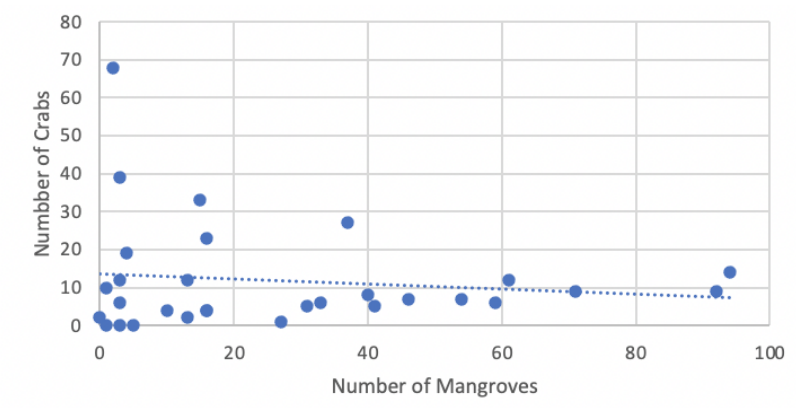

Fig 7. Scatterplot showcasing the weak adverse relationship between crab and mangrove density. Plot was constructed in Microsoft Excel version 16.43.

Crab Density as it Relates to Canopy Cover:

Canopy cover is known to correlate with tree density and yet it provides another variable for which we can test (H. S. Singh, 2013). An additional Pearson's test was conducted seeking correlation between canopy cover and crab density. Collaborative data was once again utilized for this test. No correlation was detected between crab count and canopy coverage solidifying the lack of correlation between crab density and mangrove density (α = 0.05; df = n-2; r = 0.04).

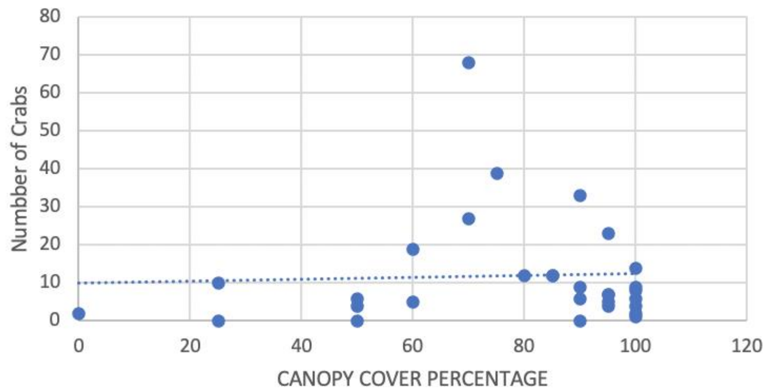

Fig 8. Scatterplot showcasing the weak positive relationship between crab density and mangrove canopy coverage. Plot was constructed in Microsoft Excel version 16.43.

Discussion

The results of this study indicate that much like mangroves, crabs exabit patterns of zonation at Mida Creek, Kenya. Species richness was found to vary significantly in zone two from zones one and three with significantly less species richness exhibited in zone 2. Likewise, species density was found to differ across all three zones being the highest in zone one with 210 individuals, followed by zones three with 79 individuals, and then zone two with 65. In this regard, I both reject the null hypothesis as well as by one tailed hypothesis that predicted crab diversity would be highest in zone two due to zone two having the most diverse mangroves. This original hypothesis was proposed following review of a similar study conducted at Mida Creek 19 years prior (Guebas et al., 2002). In attempt to understand why zone two contained significantly less diversity than the other two zones, correlation was tested for between mangrove density and canopy cover against crab density. Both tests came back as not significant leading us to reject the null and believe that mangrove density has no correlation with crab distribution within mangrove forests. This comes in direct contrast with a similar baseline study conducted in a mangrove forest in Semetan, Indonesia which found crab abundance positively correlated with mangrove structure and diversity (Ashton et al., 2003). Causal relationships for this study included mangroves as a food source, as well as protection among the root complexes (Verneirt, et al., 2002). Still other studies have found no correlation between crabs and tree species diversity (Geist et al., 2012). From these two studies, it is possible to conclude that crab distribution being correlation with mangrove distribution is site dependent. It is also possible that the cause for low correlation between flora and fauna species at Mida Creek is human interference. Mangrove crabs can be used as bioindicators with low diversity and high concentrations of singular species indicative of disturbance (Geist et al., 2012). Mida Creek was not always a protected area and has a history of mangrove exploitation (Owuor et al., 2019). Personal observations confirmed the forest on the island at the zone three study site contained red mangroves much older than the ones sampled in zone two. This may explain our low crab counts in zone two which was dominated by the red mangrove species, a species historically favored for commercial purposes (J. et al., 2017).

Our study suggests that crabs are subject to distribution patterns confined to the three zones at Mida Creek. If we reject the notion that mangroves are the causal factor of mangrove crab distribution, then other biotic and abiotic factors that influence the zonation of the mangroves may be the key. It may be that certain species of crabs and mangroves require similar environmental conditions found within distinct zones. Salinity of the soil (Naidoo, 1985), soil sulfide levels (Matthijs et al., 1999), competition between species (Clarke & Myerscough, 1993), and tidal sorting of propagules (Clarke, 1993) all play a role in the formation of zones within mangrove forest. It is likely then that several or all these factors influence the distribution of mangrove crabs. Zones one and three contained sandy soil types while zone two was thick mud. Given their affinity for sand sifting, species of *Uca* may exhibit preference for sandy soil types of characteristic of zones one and three (Kristensen, 2008). Zone two, which contained a muddy soil, was dominated by *Neosarmatium meinerti.* Similar distribution patterns were found in a mangrove forest in Australia where sediment characteristics and salinity tolerances were found to be primary drivers in crab gradients (Frusher et al., 1994). Geist et al. also found correlation between the distribution of ocypodid crabs and sediment type (Geist et al., 2012).

Although mangroves were not found to be directly responsible for the distribution of crabs at Mida Creek, it is possible the inverse is true. Mangrove crabs are classified as ecosystem engineers (Kristensen, 2008). To be labeled an ecosystem engineer, one must solicit drastic change on one’s environment. In 1987, proceeded by Smith recording an inverse relationship between seed predation and dominant tree species in forest canopies, a dominance-predation hypothesis was proposed to explain mangrove forest zonation (Smith, 1987). While we did not find correlation between mangrove density and crab density, it is possible that similar studies conducted at the species level would be illuminating in this regard.

It is surprising that only seven different species were observed throughout the three transects, especially considering fourteen species were cataloged during the prep day (Appendix A). A similar baseline study conducted in Semetan, Malesia found no less than 31 species throughout its mangrove forest; a study in Java, Indonesia found no less than 49 (Ashton et al., 2003; Geist et al., 2012). It is possible that the methodology utilized within my study played a part in identifying low crab counts. Three transects over three days is hardly sufficient to obtain an accurate population sample from the environment. Furthermore, the five-minute waiting period at each quadrat for the ecosystem to normalize following my disruption was not long enough for the crabs to re-emerge from hiding. Multiple times crabs were observed as hiding upon arrival to the study site and would not emerge throughout the duration. Fault may also lie with my sampling method. Both the Malaysian and Indonesian studies utilized a search and capture method. It is contested what sampling method for sampling crab populations is the most effective. A study from 2006 tested several foremost sampling methods for the *grapsid* crab species in Australian mangrove forest. They concluded that pitfall traps had the highest yield with their one flaw being failure to sample larger crab species such as *Neosarmatium meinerti* (Kent & McGuinness, 2006).

Further limitations to this study include the lack of preparation and rushed nature. Given the circumstances of COVID-19, study topic, planning, and implementation was expedited which did not allow for adequate planning nor carrying out of the study. Site surveys were not complete by the time our study was conducted and when we sampled zone three, it was our first time being there. Methods were tested in real time leading to some fluid methodology throughout as we tested the feasibility of our project. This led to unnecessary collection of data including water present and proximate invertebrates. Dense mangrove forests withs sharp oysters within zone two made it difficult to lay accurate transects and consistent quadrats were not always possible. Our limited data collection period of three days as opposed to three weeks led to less complete data. Had three weeks of data been collected, my data may have more closely resembled that of Ashton et al. and Geist et al. The rushed nature of our study also meant less time to survey each quadrat. Had more time been allocated to each site, more accurate crab count may have been surveyed. The ability for the ecosystem to recover from my presence was also disrupted by the ongoing mangrove study along the same zones. Transect sampling may have also been a limiting factor with pit fall traps historically being the better choice. Type of data collected also limited statistical analysis potential.

Conclusion

Our study found evidence for patterns of zonation within crab populations at Mida Creek, Kenya. The zonation detected was influenced by neither mangrove tree density nor canopy cover. In addition, our study identified 14 unique species of land crab (Appendix A), 7 of which appeared within the scope of our study. Better understanding crab diversity and distribution patterns at Mida Creek Kenya will allow for better understanding of the ecosystem as a whole and what drives the three unique zones present. Comparative studies will also allow for assessment of ecosystem degradation by using species of mangrove crabs as bioindicators (Geist et al., 2012). Such studies are integral for future conservation efforts and have failed to be taken account for in existing plans such as NMEMP.

Future research directions include the utilization of different sampling methods within the Mida Creek ecosystem such as the funneled pitfall trap which is proven to be the most effective sampling method for mangrove crabs (Kent & McGuinness, 2006). Burrow counts should also be recorded along with their size. Promising literature has proven the effectiveness of utilizing burrow counts to estimate crab populations (Li et al., 2015; Wayne P. Aspey, 1978). While I collected burrow counts for my study, failure to record burrow size rendered accurate population estimates impossible. Successful burrow sampling may negate long sampling times within each quadrat allowing more additional terrain coverage. Should this study be replicated on site, greater quantities of longer transects are also suggested for better understanding of the ecosystem. Furthermore, comparisons at the species level of both mangroves and crabs will provide greater insight into how the ecosystem works as a whole, specifically, the complex formation of mangrove forest zones.

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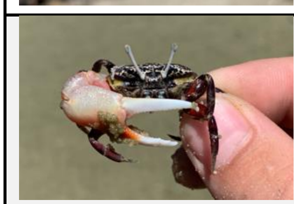
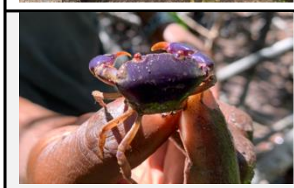
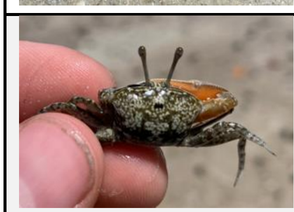
Appendix

Appendix A:

Identification chart of all terrestrial crab species identified on site

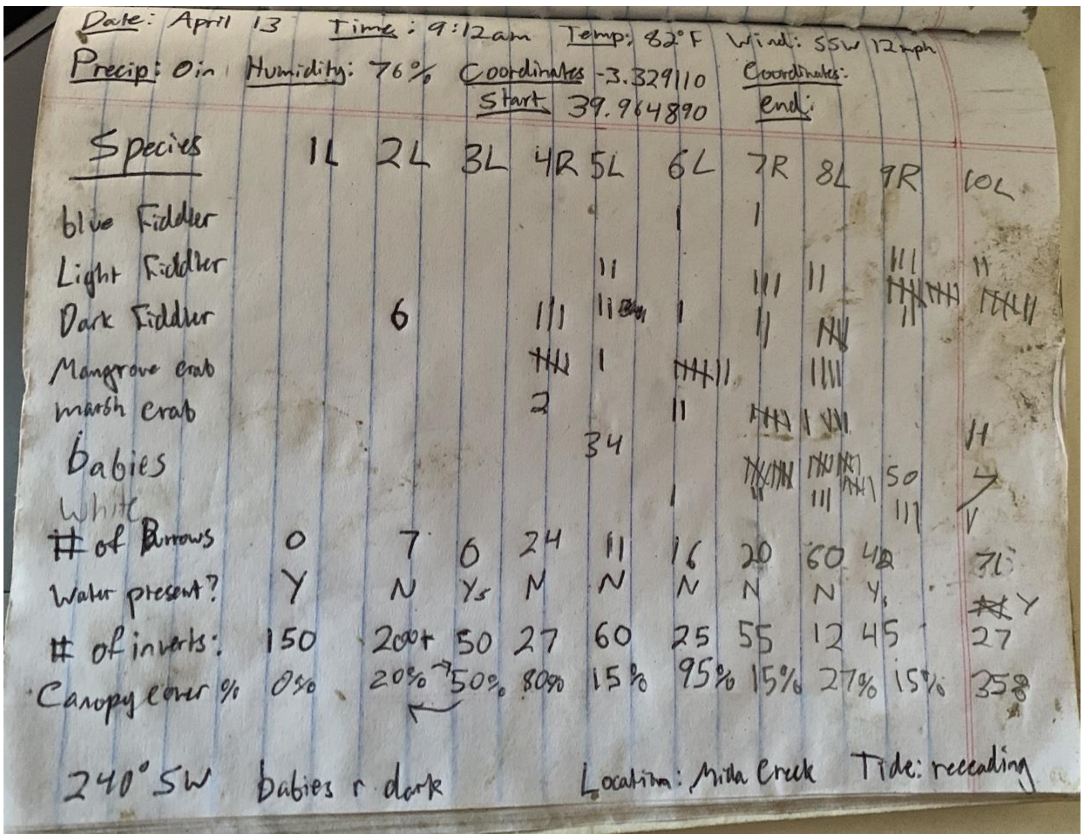
Picture	Common Name	Scientific Name	Primarily Location
	Soldier Crab	*Dotilla fenestrata*	Zone 3
	Marsh Crab	*Neosarmatium meinerti*	Zones 1 and 2
	Mangrove Crab	*Macrophthalmus boscii*	Primarily zone 2, can be found in all zones
	Blue Fiddler	*Uca urvillei*	Primarily zone 3, can be found in all zones
	Land crab	*Epixanthus dentatus*	Zone 3
	Unknown (aquatic species)	*Percnon planissimum*	Zone 3
	Dark fiddler	*Uca inversa inversa*	Primarily zone 1, can be found in all zones

	Blue Fiddler	*Uca tetragonon*	Zone 3
	Female fiddler	*Female uca*	All zones
	Mangrove crab	*Macrophthalmus miloti*	Primarily zones 2 and 3
	Light Fiddler	*Uca lactea annulipes*	Zone 1
	Land crab	*Cardisoma carnifex*	All zones, resides in burrows during the day
	unknown	*t*	unknown
	Ghost Crab	*Ocypodinae*	3rd zone, resides in burrows during the day
	Shore Fiddler	*Uca vocans var. Hesperiae*	Zone 3

	Rock Crab	*Calappa hepatica*	Zone 3

Identification was made possible by my guide Hassan, an unspecified field guide he had on hand, as well as http://www.mangrovecrabs.com/.

Appendix B: Field Notes

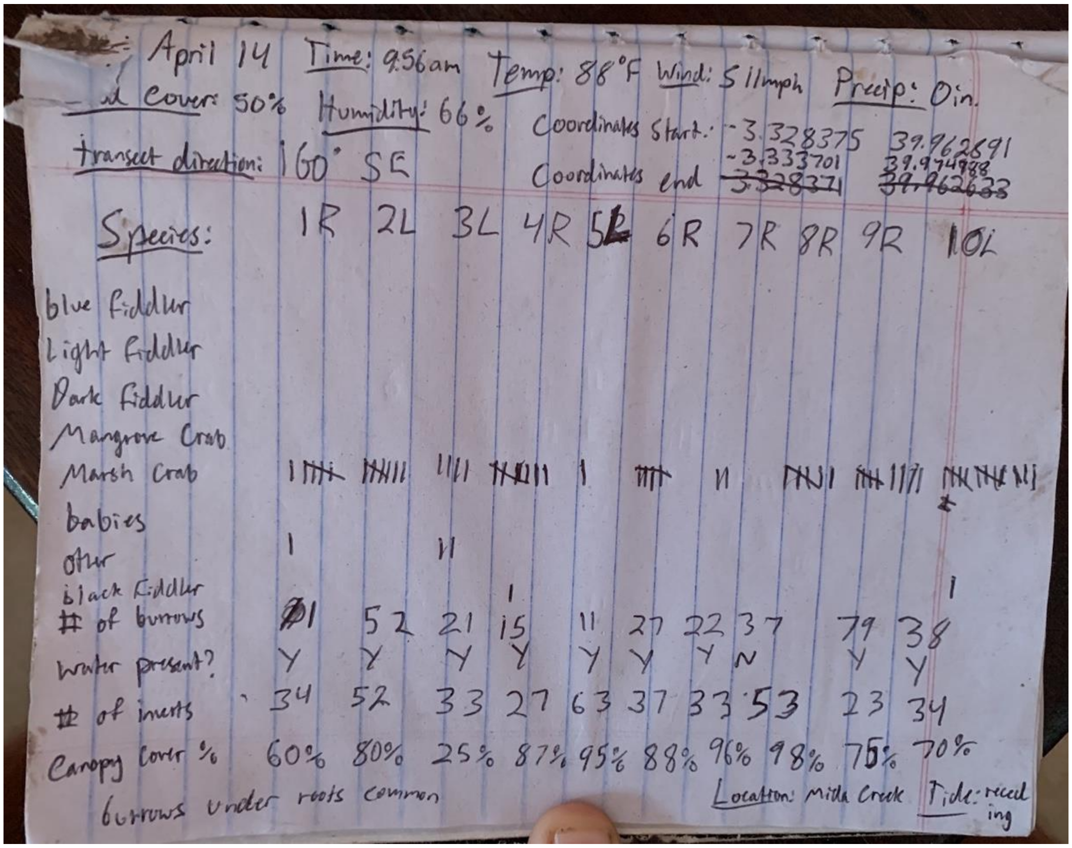


Date: April 13 Time: 9:12am Temp: 82°F Wind: SSW 12mph

Precip: 0in Humidity: 76% Coordinates Start: -3.329110 39.964890 Coordinates end:

Species	1L	2L	3L	4R	5L	6L	7R	8L	9R	10L
blue Fiddler						|	|			
Light Fiddler					||		|||	||	|||	||
Dark Fiddler		6		|||	|| [illegible]	|	||	[illegible]	[illegible]	[illegible]
Mangrove crab				[illegible]	|	[illegible]		||||		
marsh crab				2		||	[illegible]	[illegible]		||
babies					34		[illegible]	[illegible]	50	[illegible]
White						|		|||	|||	
# of Burrows	0	7	6	24	11	16	20	60	42	36
Water present?	Y	N	Ys	N	N	N	N	N	Y	~~N~~ Y
# of inverts:	150	200+	50	27	60	25	55	12	45	27
Canopy cover %	0%	20%	50%	80%	15%	95%	15%	27%	15%	35%

240° SW babies r dark Location: Mida Creek Tide: receading



_ _: April 14 Time: 9:56am Temp: 88°F Wind: 5.11mph Precip: 0in.

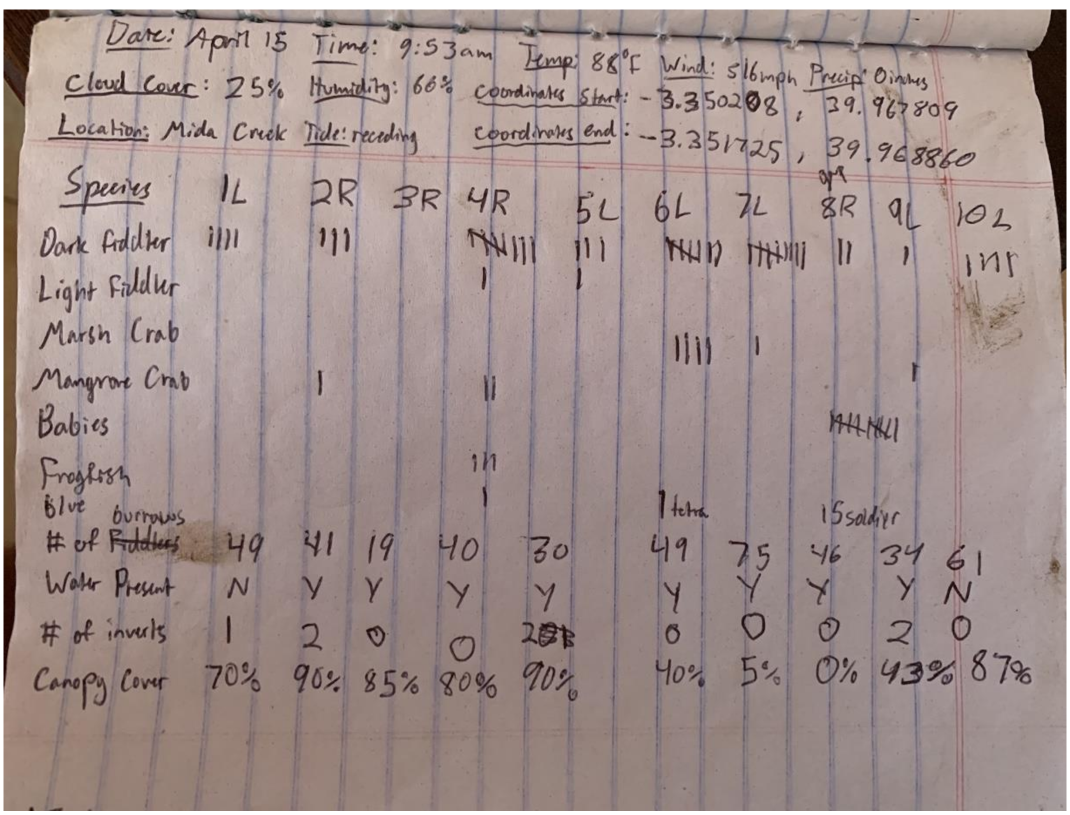
_d Cover: 50% Humidity: 66% Coordinates Start: -3.328375 39.962891

transect direction: 160° SE Coordinates end -3.333701 ~~-3.328371~~ 39.974988 ~~39.962633~~

Species:	1R	2L	3L	4R	5L	6R	7R	8R	9R	10L
blue fiddler										
Light fiddler										
Dark fiddler										
Mangrove Crab										
Marsh Crab	I卌	卌III	IIII	卌III	I	卌	II	卌I	卌IIII	卌卌III *
babies										
other	I		II							
black fiddler				I						I
# of burrows	~~2~~1	52	21	15	11	27	22	37	79	38
water present?	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
# of inverts	34	52	33	27	63	37	33	53	23	34
Canopy Cover %	60%	80%	25%	87%	95%	88%	96%	98%	75%	70%

burrows under roots common

Location: Mida Creek Tide: receding



Date: April 15 Time: 9:53am Temp: 88°F Wind: 5.16mph Precip: 0inches

Cloud Cover: 25% Humidity: 66% coordinates Start: -3.350208, 39.967809

Location: Mida Creek Tide: receding coordinates end: -3.351725, 39.968860

Species	1L	2R	3R	4R	5L	6L	7L	8R	9L	10L
Dark fiddler	IIII	III		卌III	III	卌II	卌IIIII	II	I	IIII
Light fiddler				I	I					
Marsh Crab						IIII	I			
Mangrove Crab		I		II					I	
Babies								卌卌I		
Frogfish				III						
Blue				I		1 tetra		15 soldier		
# of ~~Fiddlers~~ burrows	49	41	19	40	30	49	75	46	34	61
Water Present	N	Y	Y	Y	Y	Y	Y	Y	Y	N
# of inverts	1	2	0	0	2	0	0	0	2	0
Canopy Cover	70%	90%	85%	80%	90%	40%	5%	0%	43%	87%

Appendix C:

Nuts and **bolts** of project for posterity

Location: Mida Creek, Malindi, Kenya

Area Description: The Mida Creek Conservation Community has a local crab shack restaurant on the shore of Mida Creek. Many guides and volunteers spend their days hanging around the roofed pavilion looking for work (although this may have been exaggerated during COVID-19). We would start every day by pulling up to the parking lot and enlisting the help of one of the guides for the day. We would often leave anything extra that we didn't want to carry in the car locked in the parking lot. We also had the option to leave our extra gear in the pavilion, our relationship was good enough with the locals that they would've watched it for us. After conducting our study in the mangroves, my research partner and I would buy a drink or coconut from the crab hut and hang out for about a half hour with our guide and/or others. This served to build our relationships with the locals which opened up more opportunities for us later on.

Local Guide: Our class made a trip to Mida Creek on one of our excursions prior to our ISP studies. During this trip, our guide was named Hassan Kombo. Seeing this area as a possibility for my future study, I made sure to get Hassan's WhatsApp number before I left and stayed in contact with him. When it came time to conduct my study, Hassan was more than willing to help. He assisted me and my partner every day of the study and was very flexible. He was also helpful with questions outside the scope of our study as he is a lifelong local to the Kilifi area.

Transport: In our unique scenario, we were not allowed to live on site and so transportation would have cost significantly higher than normal. This being the case, SIT paid for our transportation over the four days that we commuted to Mida Creek. All transportation was therefore enlisted and paid for by Miltone who is an SIT staff member in Kenya. Our mode of transportation throughout our study was private cars.

Room and Board: Under normal circumstances, I would have sought room and board adjacent to my study site. Given SIT's COVID restrictions however, all students were required to live at Makuti Villas in Kilifi, Kenya on SIT's dime. It was not a bad place to stay and the staff was nice. Under different circumstances, closer accommodations would have been preferred.

Food: Adequate stipends were provided by SIT for the duration of our ISPs. During my stay, I got food from Makuti Villas (priced for tourists but was really good; best pizza in Kenya), Navas (the local grocery store), or any of the local restaurants such as Village Dishes or Village Shawarma (both priced fairly). All of these were within walking distance of Makuti Villas in Kilifi, Kenya.

Additional Notes: At one point we needed to utilize a canoe to get to a different zone of mangrove species on an island within Mida Creek. Hassan made a call and some locals brought us one within 30 minutes. At one point we were also able to visit one of the neighboring villages to sample some local cuisine. All the locals at Mida Creek were willing and able to help with whatever they could, investing in relationships with them is valuable and recommended.