Horizons

Volume 5 | Issue 1 Article 31

12-18-2020

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Available at: https://kahualike.manoa.hawaii.edu/horizons/vol5/iss1/31

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# *The Impact of Invasive Ant Species on Ghost Crab* (Ocypode spp.) *Population Dynamics at the James Campbell National Wildlife Refuge on the North Shore of O'ahu*

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Marine Biology (OPIHI Internship)
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*Invasive species pose a persistent danger to the endemic marine fauna found in the Hawaiian archipelago, threatening the ecological and economic values associated with these fragile ecosystems. This study focuses on the impact invasive ant species have on the population dynamics of ghost crabs* (Ocypode spp.) *along the northern coast of Oahu. Through* in situ *sampling techniques, ant density as well as crab location and size were determined at a total of 22 transects. Through statistical analysis, it was found that there is a significant difference in the size distribution of the ghost crab population between the sand and the vegetation. Additionally, there was found to be a negative relationship between the proportion of the crab population that lived in the vegetation when compared to ant density. Overall, this study shows the critical impacts that invasive ants may be having on the coastal environments of Oahu, altering spatial distribution patterns and potentially disrupting the natural size dispersal of the organisms living within the highly zoned intertidal region. Understanding the impacts of invasive species on coastal regions is critical to the establishment of effective management techniques that can preserve the diversity and natural functioning of intertidal regions on a global scale.*

## Introduction

The presence of invasive species on the Hawaiian islands represents a threat of high magnitude to some of the most isolated ecosystems on Earth (Pejchar 2009). The main Hawaiian Islands have been plagued by invasive animals and plants such as feral pigs (*Sus scrofa*), mongoose (*Herpestes javanicus*), and velvet trees (*Miconia calvescens*), amongst a number of other species that threaten to disturb the natural ecosystems of the islands and cause severe ecological and economic damages (Kaiser 2006; Nogueira-Filho 2009; Fox 2018). The marine environment of Hawai'i has also been found to be particularly susceptible to the threats of invasive species. Specifically, several species

My name is Sophia Rahnke and I am working toward completing my BS in Marine Biology and fulfilling requirements of the Honors program at UH Mānoa. This work was produced during my junior year of undergraduate study while I was a part of the OPIHI internship. During this internship, I wanted to learn more about the intertidal ecosystem of Hawai'i as well as the presence and consequences of invasive species in this environment. I conducted this work at the James Campbell National Wildlife Refuge, where I investigated the potential impacts of invasive ant species on native ghost crab populations and learned a lot not only about Hawai'i's coastal environment, but also about the perseverance and ingenuity that is required to conduct field work. I hope to be able to continue my passion for the field of coastal and marine ecology research in graduate school in the near future.

*Horizons*, Vol. 5, 2020, pp. 163–167
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of nonnative algae, barnacles, and the introduced Peacock grouper (*Cephalopholis argus)* have had notable impacts on marine ecosystems (Smith 2002; Dierking 2007; Zabin 2007). While generally resilient over evolutionary time scales, abrupt disturbances, such as those associated with anthropogenic changes and invasive species introduction, can severely disrupt marine communities and should be cause for concern (Godwin 2006).

One such area of concern is the presence of ants in Hawai'i, which represent a wholly introduced component of the Hawaiian ecosystem with wide ranging implications for agriculture and conservation of native species (Krushelnycky 2005). Over the past two centuries, approximately 45 ant species have been established in Hawai'i and are known to threaten native invertebrate and plant populations including notorious invasive species such as the pharaoh ant (*Monomorium pharaonis),* the big-headed ant (*Pheidole megacephala*), and the tropical fire ant (*Solenopsis geminata*) (Krushelnycky 2005; Plentovich 2009). One species, *Anoplolepis gracilipes* (yellow crazy ant), is a particularly harmful invasive ant around the world with the ability to reach unusually high densities and form "supercolonies" (Abbott 2005). This numerical dominance is often related to the species' ability to reduce the abundance of, and negatively impact, coastal species populations, such as ground nesting seabirds like wedge-tailed shearwaters (*Ardenna pacifica*) and invertebrates like Christmas Islands red crabs (*Gecarcoidea natalis*) (Abbott 2005; Plentovich 2018). In fact, yellow crazy ants have been linked to major ecosystem disruption on Christmas Island in the Indian Ocean, where the reduction of red crab populations caused severe changes in the rainforest ecosystem, negatively impacting the native fauna of the island (Abbott 2007). These concerns have made their way to the island of O'ahu with the documentation of yellow crazy ants. The impact these ant populations may have on *Ocypode ceratophthalma* and *Ocypode pallidula*, from here on collectively referred to as ghost crabs, within the James Campbell National Wildlife Refuge is unknown but potentially devastating (Plentovich 2010).

Ghost crabs are some of the largest invertebrates living on coastal shores and are found globally in a range of different environments (Hughes 2014). Ghost crabs are well known for their distinct burrowing behavior and previous studies have shown there is a direct link between crab carapace length and the size of the crab burrows present on a beach (Hughes 2014; Vachhrajani 2016). Additionally, ghost crabs have been known to exhibit specific zonation patterns, in which males inhabit the upper intertidal zone of a beach and females and juveniles inhabit the vegetation near the beach (Fellows 1966). These zoning patterns seem particularly susceptible to disruption by the presence of invasive ants, specifically *Anoplolepis gracilipes,* on Hawaiian shorelines. This study aims to determine how ghost crab population size structure responds to invasive ant density, as well as how ghost crab zonation patterns are impacted by invasive ant density. Additionally, to consider whether invasive ant populations can be associated with larger scale ecological changes such as disturbance of the natural spatial distribution patterns of organisms or reduction of mean crab size within the Hawaiian intertidal system.

## Methods

### Study Site Mapping

The James Campbell National Wildlife Refuge is located in the Kahuku ahupua'a of the Ko'olauloa district on the island of O'ahu. The Refuge is managed by the U.S. Fish and Wildlife Service (USFWS) to provide habitat for endangered Hawaiian water birds. The Refuge also provides habitat to various native plants species, as well many coastal species such as the endangered Hawaiian monk seal and threatened Hawaiian green sea turtle. The coastline of the James Campbell site is highly variable and can change rapidly. As a result, the coastline area in between Turtle Bay Resort and Kahuku Golf Course was mapped using a GPS to mark locations appropriate for sampling. The northern shore line is characterized by long stretches of rocky coastline that are unsuitable for ghost crabs, which are only found in sandy beach zones, therefore the GPS points mapped identify the stretches of sandy area in which transects could be placed at least 10 m apart (Fellows 1975). If it was not possible to place at least two transects at 10 m apart within a stretch of sand, the area was discarded. In order to do this, the entire coastline between Turtle Bay and Kahuku golf course was walked and the latitude and longitude of 24 sandy stretches were marked. These areas were then plotted on Google Earth and the length of each sandy stretch was calculated and recorded (**Fig.1**). Two points were randomly generated within each sandy stretch and these were assigned to transect locations. These points were then inputted into the GPS to allow for navigation to the assigned transects in the field.

### *Anoplolepis Gracilipes* Sampling

In order to bait the yellow crazy ants, approximately 0.2 g of Spam ©, honey, and peanut butter were placed into a Falcon centrifuge tube and placed in a shaded area at the point in

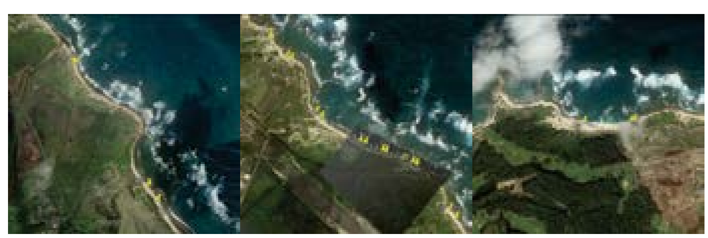

**Figure 1** Map of the northwestern coastline of O'ahu, HI. Transect sites are marked with yellow pins that indicate where sandy areas appropriate for sampling were present. Satellite photos courtesy of Google Earth.

which the crab transect was conducted. The tube remained at the site no less than 30 minutes and no more than 2 hours before being collected. A flag was placed in the sand so that the tube could easily be located upon return to the site. Upon collection, the tubes were capped, the amount of time allowed for collection was recorded and the tubes were placed in a cooler. After being frozen, the ants were brought to the laboratory, identified using a dissecting microscope, and the relative density (standardized by time of bait exposure) of the yellow crazy ants from each transect point calculated.

### *Ocypode Ceratophthalma* Sampling

Ghost crab size is known to be directly proportional to the diameter of the burrows created by the crabs (Vachhrajani 2016). Therefore, at each transect location the size population body size distribution was determined by measuring the diameter of the ghost crab burrows present in the area. A rectangular portion of the beach was sampled from the mean high tide, determined at individual transects. The boundary of one side of the sample area started from the upper limit of the swash zone to the last crab burrow that could be identified after the vegetation line. This limit varied from site to site based on the presence of burrows as well as factors such as tide or the slope of the beach and was measured using a transect tape each time a survey was conducted noting the length of the vegetation within the transect. The other boundary was standardized across all sites to be approximately 5 meters. In order for a burrow to be counted, it needed to appear as though it was freshly dug, and this was determined by the presence of a sand mound next to the entrance of the burrow and the ability to see into the burrow without it having been filled in by sand. All of the diameters were recorded, and this process was repeated at two transects of random generation within the 12 survey areas. Correlation coefficients were calculated between ant density and the proportion of crabs burrowing in vegetation and between ant density and burrow hole size. A t-test was used to evaluate the difference between the size of the burrow holes in vegetation and those in the sand intertidal zones.

## Results

A negative, although insignificant, relationship existed between the density of *Monomorium pharaonis* (pharaoh ants) and the proportion of ghost crabs with burrows in the vegetation (Correlation; df=7, r=-0.298, p=0.437, **Fig. 2**). At Transect 1, there were no ghost crab burrows found to be present in the vegetation.

In addition, no relationship was found between the average burrow diameter of ghost crabs in the sand and overall ant density. This relationship was also not found to be statistically significant (Correlation; df=16, r=0.332, p=0.179, **Fig. 3**). There were no ants found to be present at Transects 9 and 17.

There was a significant difference between the average crab burrow diameter in the sand (2.39 ± 0.20 cm) when compared to the size of those in the vegetation (1.55 ± 0.22 cm, T-test; df=34, tstat=2.78, p=0.009, **Fig. 4**). Burrow diameters were used from all transects.

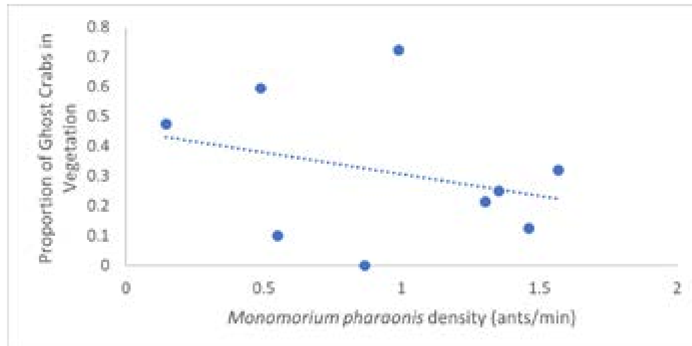


**Figure 2** Proportion of ghost crab population found in the vegetation relative to the density of *Monomorium pharaonis* (ants/min). A negative relationship existed between these variables but was not statistically significant (p > 0.01).

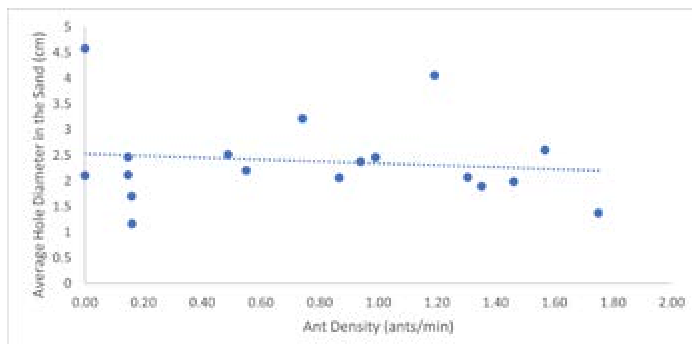


**Figure 3** Average diameter of ghost crab burrow in the sand (cm) relative to the total ant density (ants/min). No significant relationship was found between these two variables.

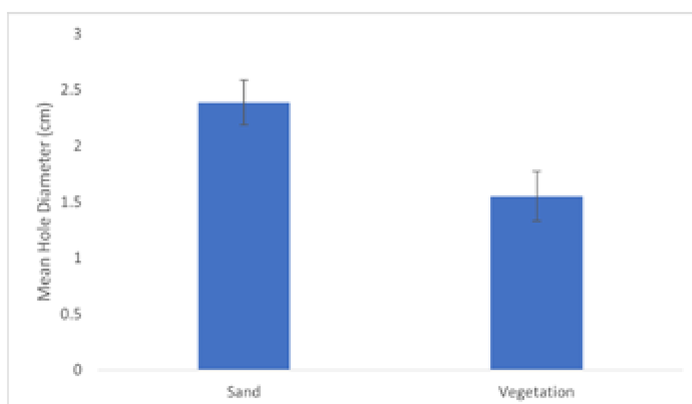


**Figure 4** Mean ghost crab burrow diameter (cm) relative to both the sand and vegetation habitat zones. The difference between the two zones was found to be statistically significant.

## Discussion

A negative, although insignificant, relationship exists between the relative proportion of ghost crabs that live in the vegetation and pharaoh ant density. The extensive presence of pharaoh ants, which were found at more than half of the transect sites, along the beaches of north O'ahu and the impact this species could potentially have on ghost crabs was an unanticipated finding of this study. Pharaoh ants are thought to have originated in tropical Asia and are one of the most ubiquitous household ant species around the world (Wetterer 2010). Pharaoh ants are notorious for their ability to transmit disease and are known to form "supercolonies" similar to those of yellow crazy ants (Beatson 1972; Schmidt 2010). While few yellow crazy ants were found at the transect sites, the presence of "supercolony" forming pharaoh ants perhaps presents a similar concern for ghost crab populations, especially given the trend of ghost crab distribution found in response to increasing density of pharaoh ants. Based on this finding, further consideration should be given to the potential impact pharaoh ants may have on the coastal environment of Hawai'i. While there was no significant trend found in this study, there is potential indication that the presence of pharaoh ants drives ghost crabs out of the vegetation, possibly altering the natural zonation pattern of ghost crabs on Hawaiian shores. In this instance, it is also relevant to note the possible impact of limitations such as the sample size, variable weather conditions, and seasonal fluctuations that may have contributed to an outcome not as incisive as was anticipated.

Additionally, there was found to be no relationship between the size of the ghost crabs living in the sand and ant density, another unanticipated result of the study as it was expected the density of ants would impact the average size of the ghost crab population in an area. It was also found that there was a significant difference in the size of ghost crabs living in the sand and in the vegetation zones, with significantly larger crabs living in the sand. In Hawai'i specifically, it has been found that males inhabit the uppermost intertidal and dry beach zone, while mature females and juveniles inhabit the vegetation directly adjacent to the beach (Fellows 1975). These results suggest that the vegetation zone is perhaps one of critical ecological importance to ghost crab populations, specifically for the survival of young crabs and females with the ability to reproduce.

Therefore, the introduction of invasive species, such as the yellow crazy ant or pharaoh ant, is perhaps threatening the natural zonation and spatial distribution patterns of ghost crabs on Hawaiian beaches. The intertidal zone that exists further up the beach lacks waves as a controlling factor for organisms (De Ruyck 1996). This creates a unique zone with the potential for high diversity to exist, meaning the forces of biological interactions likely will have a higher impact in this area than on wave-dominated beaches (De Ruyck 1996). The importance of biological interactions in this region makes the presence of invasive ants particularly alarming, specifically with the ability of yellow crazy ants and pharaoh ants to create high-density supercolonies (Abbott 2005; Schmidt 2010). Yellow crazy ants have been known to form these supercolonies on other oceanic islands, killing endemic red crab populations and contributing to "invasional meltdown" in extreme cases such as on Christmas Island where the native flora and fauna experienced losses in biodiversity and drastic changes in ecosystem structure as a result of the negative impacts on red land crabs (Abbott 2006; Thomas 2010). The results of this study indicate that supercolony forming ant species found on the beaches of Hawai'i perhaps have the potential to have similar impacts upon ghost crabs, conceivably negatively impacting ghost crab populations and altering the natural intertidal ecosystem.

This study evaluated the potential impact invasive ant populations could have on just one aspect of the Hawaiian intertidal ecosystem. Through looking at the specific spatial distribution patterns of ghost crabs we are better able to understand the disturbance caused by different species of ants through an ecological lens. However, in other ecosystems in which ghost crabs are not known to display significant zonation patterns these findings many not be as relevant (Fellows 1975). Evaluating these factors at other locales around the world would be the next steps in better evidence of the ecological disturbance that can be associated with invasive species such as yellow crazy ants or pharaoh ants. The importance of ghost crabs in intertidal regions as predators, scavengers, and even as indicators of overall habitat quality is undeniable, meaning a disturbance to ghost crab populations will likely be reflected throughout the rest of the ecosystem (Wolcott 1978; Brook 2009). With the primary causes of decreases in biodiversity in tropical ecosystems being habitat loss and introduction of invasive species, studies such as this that evaluate the impact of invasive species on critical aspects of fauna ecology are of particular relevance (Brook 2009). This makes understanding not only how invasive ants impact an ecosystem but also understanding the mechanism by which this disturbance occurs especially important to potential conservation and restoration efforts and to the protection of native island fauna in the future.

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