Investigating spawning of *ʻAlamihi* (*Metopograpsus thukuhar)* in relation to the Hawaiian lunar calendar and tidal changes

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ABSTRACT

Loko iʻa, traditional Hawaiian aquaculture systems, were essentially sustainable refrigerators for the people of Hawaiʻi. *Loko iʻa* rely on saltwater and freshwater inputs to create a brackish water environment that attracts various marine life to feed within. The *ʻalamihi* or *Metopograpsus thukuhar* is an understudied crab that is commonly found in rocky and muddy brackish environments, including *loko iʻa*. This study took place at Honokea *loko iʻa* located at Waiuli in Hilo, Hawaii. The objective of this project was to observe the timing and abundance of *Metopograpsus thukuhar* spawning in comparison with the native Hawaiian lunar calendar and tidal changes. Although *ʻalamihi* are plentiful in Hawaiʻi, very little information is known about their life history and ecological contribution, especially in relation to *loko iʻa.* Many marine organisms time their reproduction to release planktonic larvae or gametes on nights around new and full moons (Palmer 1995). A total of nine nights between September and December 2019 were sampled, such as *Hilo* (new moon) within the *hoʻonui* (waxing) period, *Mahealani* (full moon) that fell within the *poepoe* (rounded) period, and *ʻOlekūlua* (quarter moon) that fell within the *hoʻēmi* (waning) period, and tidal data were recorded. Three people collected crabs by hand for a duration of 30 minutes each night. The crabs were sexed and carapace width was measured, and it was noted if a crab was carrying eggs or had a soft shell, which could indicate a recent molt. Each crab was then marked with a symbol to prevent recapture. A total of 116 crabs were captured, 73 females and 43 males, with 9 carrying eggs during the full moons compared to 1 individual during the new moons. Results show that *ʻalamihi* are most likely to be carrying eggs during the *poepoe* phases, and that tidal change seems to have little to no effect on spawning. Abundance and size was also compared between sexes. Few studies have been conducted on these Indo-Pacific crustaceans, but they play a key role in aquatic ecosystems and food webs, and are abundant in our *loko iʻa* systems.

INTRODUCTION

The *Metopograpsus thukuhar*, commonly known in Hawaiʻi as the *ʻalamihi* crab, is a brackish water crustacean that is found throughout the Indo-Pacific regions (Fratini et al. 2000). This understudied crab is mainly found on rocks and in mudflats, or commonly dwells among mangroves near calm bays and estuaries. *M. thukuhar* generally attains a carapace width of 2 inches, and like most crab species, they act as shredders, collectors, grazers, and predators that affect the fundamental components of aquatic and riparian food webs (Talamoni 2016). A Hawaiian *ʻōlelo noʻeau*, or traditional proverb, indicates its scavenger traits as described: "*ʻAlamihi ʻai kupapaʻu*, a corpse-eating black crab (Pukui 1983)." Crabs in general have been recognized as potential indicators of water quality within these ecosystems (Yeo et al. 2008). In Hawaiʻi, *M. thukuhar* are commonly associated with coastal mangroves, usually living on and under roots, or within mud holes, near brackish environments. Additionally, this species is commonly found at *loko iʻa,* also known as traditional Hawaiian aquaculture systems, along the coast in Hawaiʻi.

Loko iʻa have been traditionally known as a reliable source for fresh seafood, and commonly referred to as a community refrigerator. These impressive aquaculture structures have been carbon dated to as early as the 1400s, and they may have been constructed even earlier (Kikuchi 1976). The main function of *loko iʻa*, was to raise fish, typically herbivorous, such as *āholehole* (Hawaiian flagtail, *Kuhlia sandviensis*), *ʻamaʻama* (mullet, *Mugil cephalus*), and *awa* (milkfish, *Chanos chanos*), through using freshwater springs and salt water that created a thriving nutrient rich environment for them to feed within (Kikuchi 1976). Since herbivorous fish were the main food source harvested from *loko iʻa*, it was important to observe and understand the primary productivity as well as the diverse *loko iʻa* food web. Other crustaceans found at *loko iʻa* include, but are not limited to, *ʻōpae huna* (the indigenous shrimp, *Palaemon debilis*) and *hapawai* (the gastropod, *Theodoxus vespertinus*).

Although *loko iʻa* supports a diversity of organisms, the dominant species of fish prized by people were milkfish and mullet. Due to estuarine characteristics of *loko iʻa*, these ecosystems are highly productive, which maximized the cultivation of these herbivorous species by traditional fishers (Keala et al. 2007). Other species, such as crustaceans, play an important role in the *loko iʻa* food web in order to keep the yield of primary production consistent and controlled. For example, zooplankton feed on bacteria or phytoplankton, and are eventually fed upon by other fish, as well as crustaceans such as the *ʻalamihi*.

In order to best manage these systems, it was traditionally important to make keen environmental observations and an understanding of changing environmental conditions particular to each place. The changes in moon phases and associated tidal differences play a significant role in determining management strategies for fishpond practitioners as well as farmers. For example, low tides are best for harvesting rocks and constructing walls for *loko iʻa.* More importantly, paying attention to these environmental cues determined when species would be harvested by the community or left to thrive, such as when they might be spawning (Keala et al. 2007). Ultimately, it was this understanding and intimate relationship to place or location that defined times for stock recruitment or harvesting throughout seasonal changes.

Terrestrial and marine species rely on seasonal and environmental changes such as phases of the moon that trigger recurring biological and ecological processes. Changes in the moonphase prompt biological behaviors such as spawning, feeding habits, migration, and aggregation. The moon's gravitational pull on earth is the principal cause of the tides. Diverse marine species show specific spawning practices in relation to certain tidal changes, which are ultimately correlated with the changes of the moon (Skov et al. 2005).

Well known mass spawning examples include corals that spawn on a few full moon and last-quarter moon nights per year (Harrison et al. 1984) and the South Pacific Palolo worm (*Palola viridis*) that spawns yearly on a single day near the last quarter of the moon (Caspers

1984). There have been previous studies that have investigated many reasons for these biological patterns, especially related to spawning. For example, spawn released during nights without moonlight could reduce predation by visual hunters, or the light of the full moon might assist migration to spawning sites (Skov et al. 2005). Many coastal populations time their reproduction to release planktonic larvae or gametes on nights around new and full moons (Palmer 1995). Since tides and moon phases are correlated, it is difficult to determine whether these biological trends are directed by moon phase or tidal change, although, one study suggests that for crabs, larval release mainly coincides with tidal amplitude (Morgan 1996).

MATERIALS AND METHODS

STUDY SITE: HONOKEA LOKO I'A

Honokea *loko i'a* (Fig. 1), is a functioning Hawaiian aquaculture system located at Waiuli (Richardsons Beach Park) on the east end of the Keaukaha coastline. Waiuli is currently a part of, and partially maintained by, the County of Hawai'i and is a popular beach destination for locals and tourists. Honokea *loko i'a* is managed by a non-profit organization called Hui Ho'oleimaluō, which was founded by Kamala Anthony, as well as other individuals of the community. Along with direct management from the organization, many volunteers come to contribute, such as on annual community work days. The goal of their work is to provide opportunities for STEAM (Science, Technology, Engineering, Arts, and Mathematics) skill building, place based learning, and community engagement through the maintenance and management of *loko i'a* ecosystems. The main mission of Hui Ho'oleimaluō is to nourish Hawaii's *loko i'a* through hands-on education, community advocacy, and place-based management of natural resources (hooleimaluo.com).

COLLECTION PROCESS

Both male and female crabs were collected to investigate carapace size differences and abundance by gender. Due to the nocturnal activity of *M. thukuhar*, collection times took place during the evening hours, to maximize potential individuals caught. Crabs were collected on a total of nine moon phases (3 new moons, 3 quarter moons, and 3 full moons). Tide height was also noted according to the NOAA website. Three people searched for and collected crabs along the *loko i'a*, in addition to on adjacent mudflats and within rock crevices for a duration of 30 minutes. Each crab was sexed, its carapace was measured using a digital caliper and it was noted if females were carrying eggs and/or if soft-shell crabs were found, as it may be an indicator that they had recently molted (Taylor 2003). Additionally, each crab was marked using a white permanent paint marker and released with a different symbol (i.e, square, circle, cross, etc.) to

indicate different collection days. Although moulting and removal of the paint due to natural causes may occur in between our collection dates, it is a good method to limit recapturing as much as possible, but also to see the progress if recaptured.

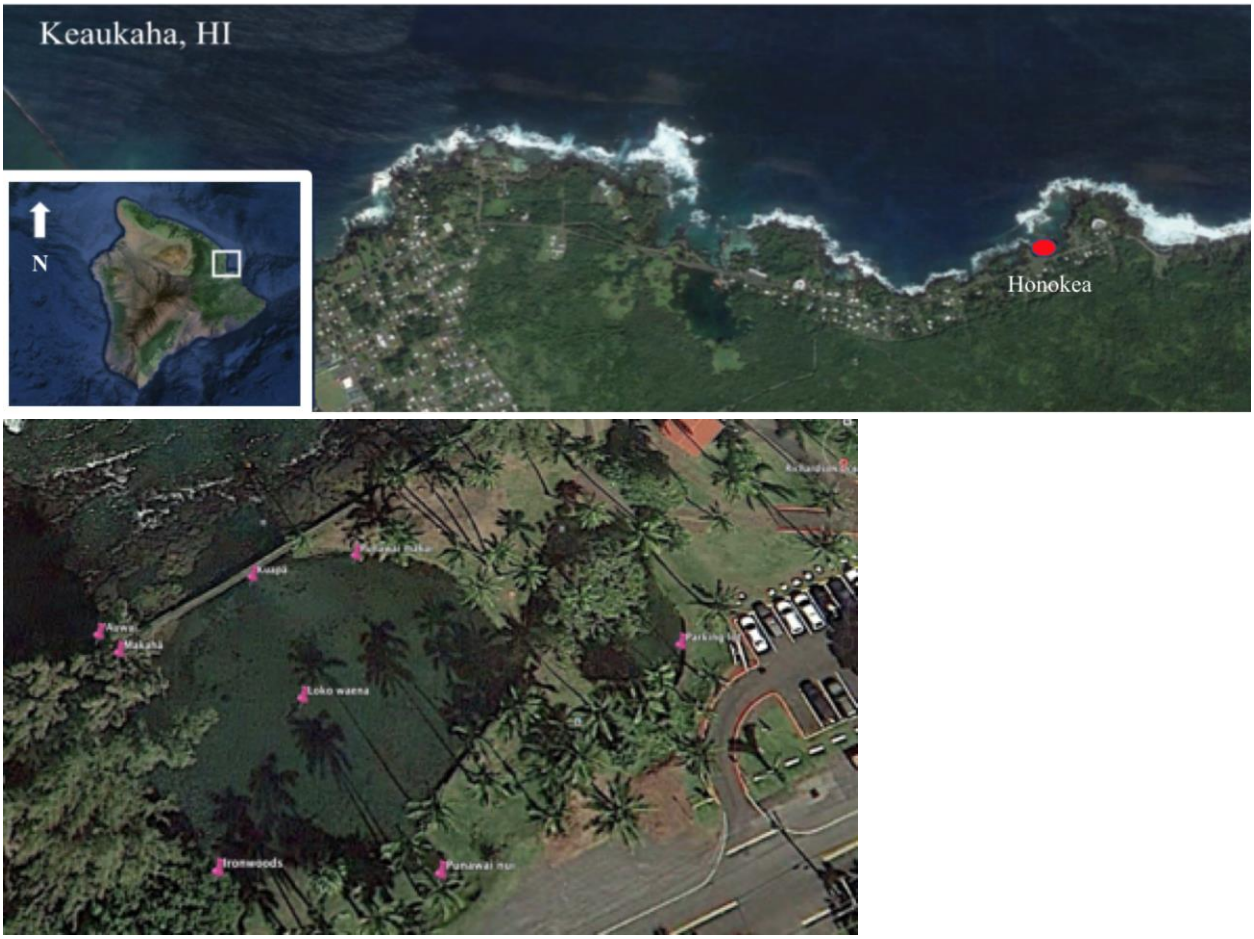

Fig. 1. Aerial images of Honokea *loko i'a* along the Keaukaha coastline in Hilo, HI, USA.

STATISTICAL ANALYSIS

Data were assessed using the Statistical Program R to investigate the relationship of eggs being present between moon phase and tidal changes as well as soft shell presence in comparison to moon phase and tidal changes. This comparison was calculated using the Fishers Exact test. Additionally, median carapace width (mm) between male and female crabs were compared using the Kruskal Wallis test.

RESULTS

A total number of 116 individuals were caught between September and December of 2019 at Honokea *loko i'a*. In order to determine the most common size of *'alamihi* at Honokea,

median carapace widths (mm) were compared (Fig. 2). There was no correlation in carapace width between sexes. Carapace widths of females were also considered to explore if there was a particular mature size when they carry eggs. There were no common trends in relation to females carrying eggs and size as the smallest female with eggs measured 13.15 mm and the largest female carrying eggs measured 27.16 mm.

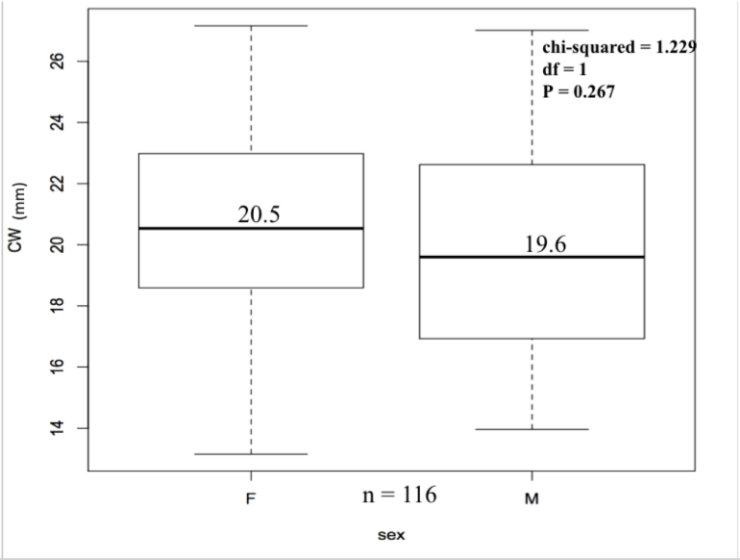

Fig. 2. Median carapace width compared between males and females.

The Fishers Exact Test was used to best analyze the data size given comparing soft shell presence in addition to crabs carrying eggs during moon phase and tidal changes. The highest tide calculated during collection measured 1.18 ft while the lowest tide measured -0.2 ft. Individuals with a soft shell were most abundant during low tides and full moons (Fig. 3), while individuals with eggs were most abundant during low tides and new moons (Fig. 4).

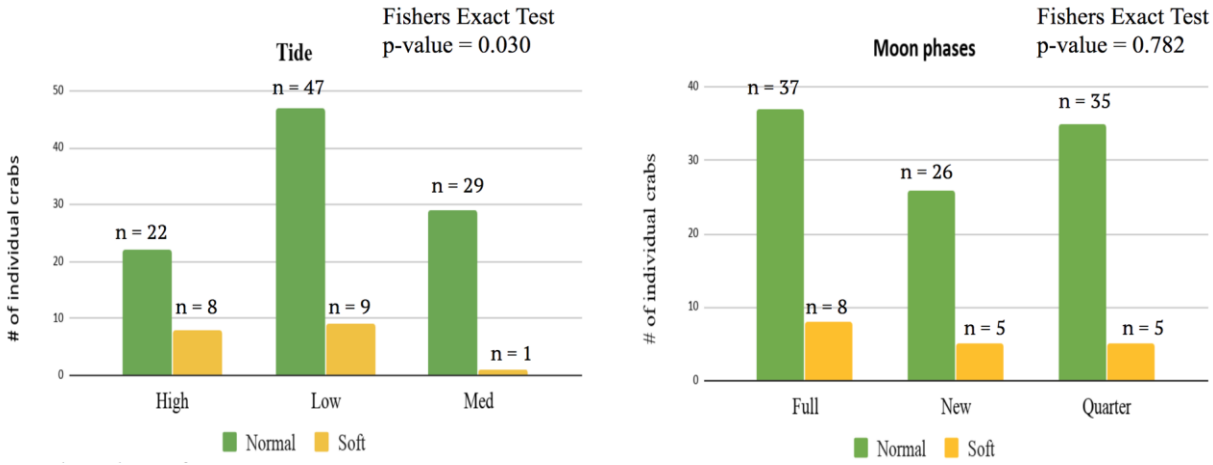

Fig. 3. Number of individuals with soft shell presence compared to tidal and moon phase changes.

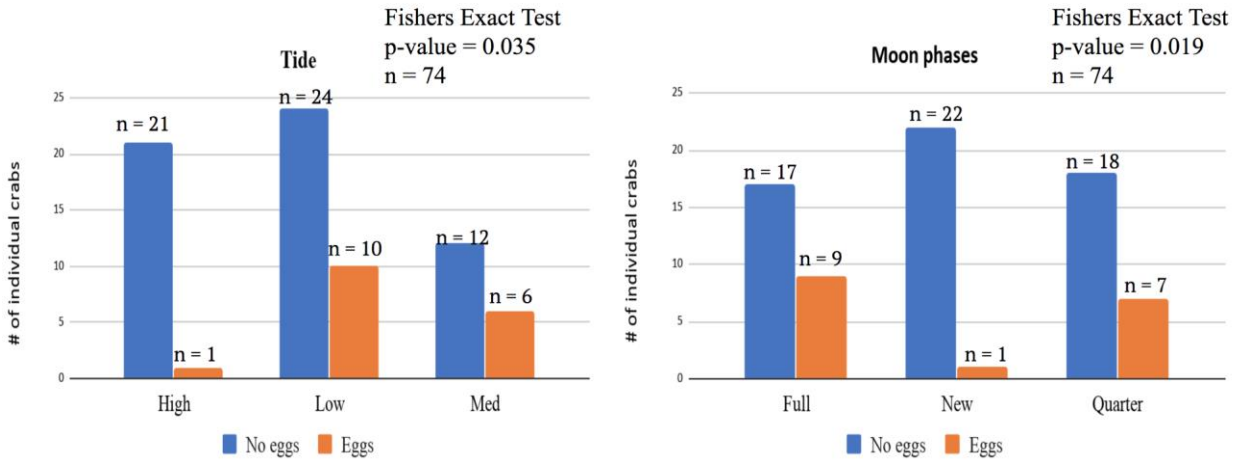

Fig. 4. Number of individuals carrying eggs compared to tidal and moon phase changes.

DISCUSSION

Based on the results, it's ultimately difficult to determine if *'alamihi* synchronize their spawn release according to tides or moon phases. There is an association between soft shell presence and tidal amplitudes, but no association with moon phase changes. Although there is an association between crabs carrying eggs with tidal amplitudes and moon phases, a larger sample population size would be needed to further investigate this relationship. The fewest crabs carrying eggs were found on new moons, possibly indicating a recent release. This could be due to the limited light of the new moon, which may be an ideal time for *'alamihi* to release their spawn in hopes to avoid possible predators (Skov et al. 2005). There is a trend of individuals that were carrying eggs seen decreasing from full to quarter to new moons. This is suggesting that the optimal release period of spawning for these crabs could fall between new and quarter moons. Lastly, very few *'alamihi* with eggs were found during high tides, but some with a soft shell were found during high tides. Many intertidal crabs tend to release their spawns during nocturnal high tides to avoid predatory fish. The soft shell presence could be a supportive conclusion that they recently molted due to a recent release of eggs (Skov et al. 2005).

CONCLUSIONS

This study provides a fair insight of the spawning activity of the *'alamihi* crab at Honokea *loko i'a*. As an understudied crustacean, there is a lot of room to further investigate this project in future studies. Considering differences in seasons within Hawai'i could be useful to see if there are certain months that *'alamihi* spawn more often out of the year or if spawning is year round. Further investigating abiotic features such as temperature and salinity as potential variables could also be useful. Finally, improving tracking capabilities would give us more accurate information in order to detect specific days that spawns were released.

This research would not be possible without the community efforts in restoring Honokea *loko iʻa.* This information will hopefully provide *loko iʻa* practitioners as well as local schools in the area with more knowledge of *ʻalamihi*. Although *ʻalamihi* are not excessively harvested for food these days, we do know that it was practiced in the past. As a food source, knowing the spawning of any organism is important in order to practice sustainable harvesting. Despite not being commonly harvested, *ʻalamihi* still play key roles as scavengers. *Loko iʻa* thrive with diverse species, therefore the more we understand each individual species such as *ʻalamihi*, we then begin to understand its function within *loko iʻa* and its contribution to its health.

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