Prevalence of shore crabs in San Juan Island via crab survey

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Abstract

As the effects of global warming increase the frequency and scale of stressful environmental conditions, it has become more and more important to understand how we can support local ecosystems adapt and stay healthy. To do this, the general abundances and dynamics of different species in individual ecosystems must be understood, thus providing the bases of healthy ecosystems. Shore crabs play important ecological roles in their ecosystems, as both scavengers that eat almost anything and as prey for animals such as sea birds and fish. The goal of this study was to conduct crab abundance surveys and compare data from this project to that of previous years (Yamada, 2021). From the previous data, it was expected that yellow shore crabs would be the most common species counted. The results show that abundances of local crab species have been consistent throughout the years of 2013-2024. It was also understood that shore crabs have preferences in

Introduction

Cancer gracilis (Graceful rock crab or GRC), *Hemigrasphus oregonensis* (Yellow shore crabs or YSC), *Hemigrasphus nudus* (Purple shore crabs or PSC), and *Pugettia gracilis* (Graceful kelp crabs or GKC) are shore crab species found commonly in coastal Washington waters. These species are vital in their ecosystems as both herbivorous and carnivorous consumers as well as a food source for shorebirds, sculpins, and other intertidal predators (Cowels, 2006). In short, the crabs help provide balance to the food webs and therefore the entire ecosystem. However, as climate change increasingly affects water temperatures and quality, ecosystems are put under heavy stress from the drastic changes. In the Pacific Northwest, sea level rise has been expected to reduce shoreline ecosystems, including mudflats, greatly compromising the species presence and abundance of every species in those ecosystems (Dalton et al., 2013). Although intertidal organisms such as shore crabs are known to have large ranges of temperature tolerance due to their historical and evolutionary exposure to harsh conditions, they nonetheless experience stress in warmer waters. Changes in water temperatures have the potential to strongly affect the timing and mortality rates during different life history stages of crustaceans such as shore crabs (Azra et al., 2019; Quinn, 2017). Such changes could cause shifts in crab population dynamics and therefore imbalance in the food webs and ecosystems that they are part of.

Furthermore, warmer waters in the Pacific Northwest are of concern as a major factor of the recruitment of invasive crabs. The European Green Crab (*Cancer maenas,* or EGC) is a globally invasive species that has caused immeasurable damage to the health of many ecosystems and countries from outcompeting local species to causing fishery collapses (Behrens-Yamada, 2008; NOAA, 2024). EGC have not been able to invade the Pacific Northwest due to the colder waters being inhospitable to crab larvae but have been observed at several places along the West Coast as water temperatures rise. The study site of this project, San Juan Island, located off of mainland Washington State, has had little exposure to EGC (WSG, 2024). The abundance patterns of native species before the establishment of EGC on San Juan Island is critical to providing a data set for comparison of before and after EGC have invaded the area. Previous surveys have estimated crab species abundances across four mudflats (False Bay, British Camp, Argyle Lagoon, and Westcott Bay) on San Juan Island, WA during the summers of 2013-2021 (Yamada, 2021). The surveys found that 97% of all crab species surveyed from 2013-2021 were YSC. The aim of this project was to update the crab abundances data bank by adding 2024 data for two previously sampled sites, Argyle Lagoon and False Bay, to investigate whether and how the species abundances have changed since the last survey in 2021.

Sea surface temperatures rose steadily in the Pacific Northwest with no notably sharp increases during 2021-2024 (O'Hara, C. et al., 2017). Because the rise in temperatures was relatively steady during the years the crab surveys were not done, it could be assumed that shore crab populations are not under severe heat stress (Johnson et al., 2023; Heeter et al., 2023). Thus, the combined crab species abundances at Argyle Lagoon and False Bay were hypothesized to have no significant difference when compared to the combined crab species abundances at Argyle Lagoon and False Bay in 2013.

Methods

Sample collection and analysis

Crab traps were initially used in an attempt to survey the abundance of crab species on two mudflat sites, Argyle Lagoon and False Bay, on San Juan Island (Figure 1). However, the crab traps were unable to catch any crabs and thus provided no usable data for the first four days of data collection. Random transects of square quadrats were determined to be reliable substitutes to crab traps to estimate the abundance of crab species. While survey duration and style differed from past surveys, transect sampling provided a larger and therefore better estimate of crab abundance than the crab traps. Nine random square quadrats were taken per site and all counts for each species were averaged for each site. These averages were used as representations of the general crab species abundance of the sites.

Figure 1 – Study sites marked in red on San Juan Island, WA

Crab Trapping Methods

Each site was visited three times, and at each site two traps were deployed at mid-high tide using a mix of oily dog kibble and wet cat food as bait (Araya-Schmidt, 2019). The mid-high tide area was determined to be 150 meters out from the beachline for False Bay and 50 meters out from the beachline for Argyle Lagoon based on the Daft Logic Area Calculator Tool (Figures 2 and 3). The beachline refers to the shoreline on each beach where the water and the land meet on Figures 2 and 3. The baits were chosen for their oil and protein content to attract crabs. The traps were opened 23 hours later and captured crabs were counted and identified. Crabs were released after data were recorded. In total, there were 6 crab trap sets per site and therefore 12 abundance data points used in the study to provide a representation of the crab abundance for each mudflat. Since the crab trapping method resulted in no captured crabs, a quadrat sampling method was used instead.

Figure 2 - The mid-high tide area of False Bay that was surveyed is outlined in red and highlighted in green. The length from the innermost point on the beachline to the boundary line is 150 meters.

Figure 3 - The mid-high tide area of Argyle Lagoon that was surveyed is outlined in red and highlighted in green. The length from the innermost point on the beachline to the boundary line is 50 meters.

Quadrat Surveying Method

Random sampling using a 0.25m^2 quadrat was the method used to collect the crab abundance data in False Bay and Argyle Lagoon. Each survey started at the beachline of the site, as the goal was to survey the mid-high tide crab population abundances. Sampling locations were chosen using a random number generator. For each quadrat, there were two walking phases that were each in random directions. A random number generator first produced a random number from 0-360 to determine the direction to walk in, and another random number generator produced a number from 0-200 to determine the number of steps to take. A smartphone compass app was used to align with the direction in which to walk, provided by the first random number generator. The random number provided by the second random number generator dictated the number of steps taken in the direction determined by the first number generator. This procedure was conducted twice to increase randomness before each quadrat was placed directly in front of the last step taken and then surveyed. After the two sets of random walking, rocks were upturned to search for crabs within each quadrat for a duration of two minutes. All individuals found within the quadrat were placed in a plastic container to be counted and identified after the counting period. All specimens were identified and their data recorded, then were released at the site of the quadrat. After the sampling was complete, water temperatures data at each site were collected using a thermometer. Nine quadrat samplings were conducted at each site for a total of 18 quadrats for the entire project.

Several assumptions and biases were made for this sampling technique. First, it was assumed that the high-mid tide range would be 150 meters from the beachline at False Bay and 50 meters from the beachline at Argyle Lagoon. It was then assumed that using 2 sets of random directions and numbers of steps from the beachline would suffice for the sampling within those boundaries.

Data Analysis

The data collected in this project were analyzed in two main sections. Species abundance was determined by totaling all counts per species and dividing them by nine to get an average of crab species abundance across all nine quadrats at that site. First, the 2024 species abundance data were compared between Argyle Lagoon and False Bay using a t-test to see if there was a significant difference in the sites' species abundance. The t-test was chosen to analyze data for this section as the goal was to determine if there is a significant difference in the averages of two variables. In this case, the variables were the averages of crab species abundance in Argyle Lagoon and in False Bay. Significantly different results could imply that there may be environmental conditions that cause shore crabs to prefer one site over the other. Secondly, combined data from both False Bay and Argyle Lagoon were compared with 2013-2021 data using an ANOVA test to determine if there was a statistically significant difference between crab abundances from 2013 and 2024 (Yamada, 2021). An ANOVA test was chosen to analyze data from this section, as the goal was to identify whether there was a significant difference in the averages of more than two groups of data. In this case, the variables were the crab species and average crab species *abundance* for each of the following years: 2013, 2014, 2016, 2018, 2021, and 2024. Significant results from these tests could imply shifts in crab abundances at San Juan Island over time in response to changing environmental conditions.

The null hypothesis for the first section comparing the species abundance between Argyle Lagoon and False Bay was that there would be no significant difference in the average of crab species abundances between the two sites. The alternate hypothesis was that False Bay would have a higher crab abundance than Argyle Lagoon. The null hypothesis for the second section was that there would be no significant difference in crab species abundance between 2013 and 2024. My alternate hypothesis was that there was a change in crab species abundance over the range of 2013 and 2024. Several graphs were built to visualize these results. Individual scatter plots for Argyle Lagoon and False Bay show the abundance of all crab species (y-axis) recorded over time (x-axis). A pie chart shows the abundance of all crabs counted in the quadrats in 2024.

Results

Location		Crab species and their abundances				
		YSC	PSC	GKC	GRC	EGC
	False Bay	31	9	0	0	0
	Argyle Lagoon	75	1	0	0	0

Table 1 – The combined totals of crabs recorded grouped by species and sites in 2024.

There were 31 YSC and 9 PSC counted in False Bay and 75 YSC and 1 PSC counted at Argyle Lagoon (Table 1). No GKC, GRC, or EGC were observed in either of the sampling sites. The averages of the YSC and PSC at False Bay were 3.44 and 0.44, respectively. The averages of the YSC and PSC at Argyle Lagoon were 8.33 and 0.11, respectively. The majority of the crabs that were counted were YSC at 96%, and the rest of the 4% were all PSC. Overall, Argyle Lagoon had a higher average crab count when compared to False Bay. False Bay had a smaller YSC:PSC ratio, whereas Argyle Lagoon had a larger YSC:PSC ratio.

The t-test comparing the difference in mean species abundance between False Bay and Argyle Lagoon showed that there was a statistically significant difference between the site abundances ($p=0.04$). Therefore, the null hypothesis stating that there would be no difference in crab abundance between the two sites was rejected. This was unexpected; it was expected that two sites would have similar crab species abundances as they are both wave-protected mudflats. The ANOVA test comparing a difference in species abundance over the years showed that there was no statistically significant difference in crab species abundance over the range from 2013 to 2024 ($p=0.42$). Therefore, the null hypothesis stating that there would be no difference in crab species abundance over time was not rejected. This was expected, as it was assumed that levels of heat stress were assumed to be relatively steady over the course of 2013-2024 (Johnson et al., 2023; Heeter et al., 2023).

Crab species abundance data from 2024 were added to and compared with the crab species abundance data from 2013-2021 for False Bay on a graph (Figure 4). This figure shows a trend of an overall decline in YSC. There was also a trend of PSC, GKC, GRC, and EGC having consistently low or zero counts in surveys taken from 2013-2024. Crab species abundance data from 2024 were added to and compared with the crab species abundance data from 2013-2021 for Argyle Lagoon in a different graph (Figure 5). This figure revealed a couple of trends in crab species abundances over time. Similar to the trend in False Bay, all crab species except for YSC had little to no counts in all surveys from 2013-2024. Another trend in the Argyle Lagoon graph is the sharp increase in YSC counted from 2018 to 2021. Although the average number of YSC counted in surveys was less than one from 2014-2018, an average of eight YSC was counted in surveys conducted in 2021 and 2024.

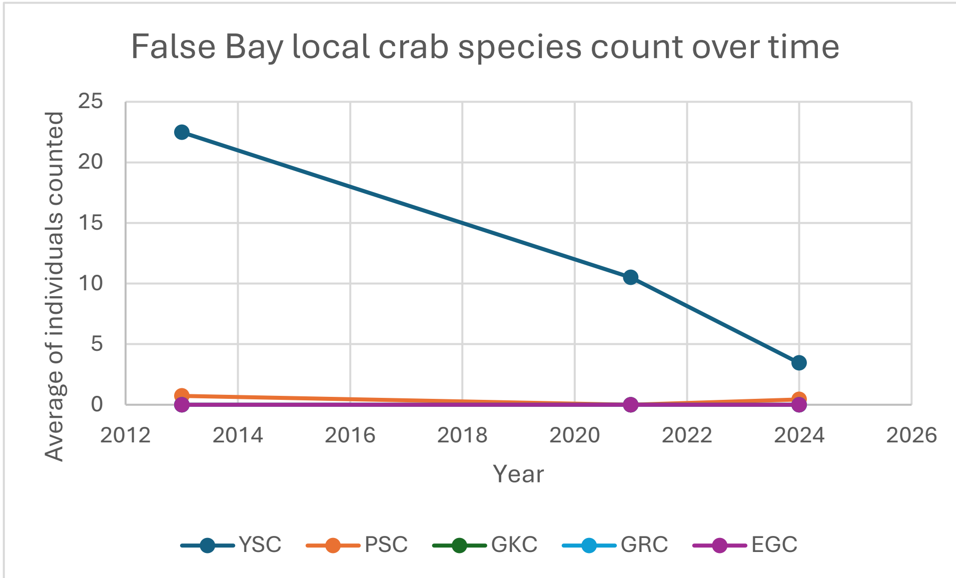

Figure 4 – The averaged crab species abundances at False Bay plotted over time. All data points provided by previous surveys are plotted above.

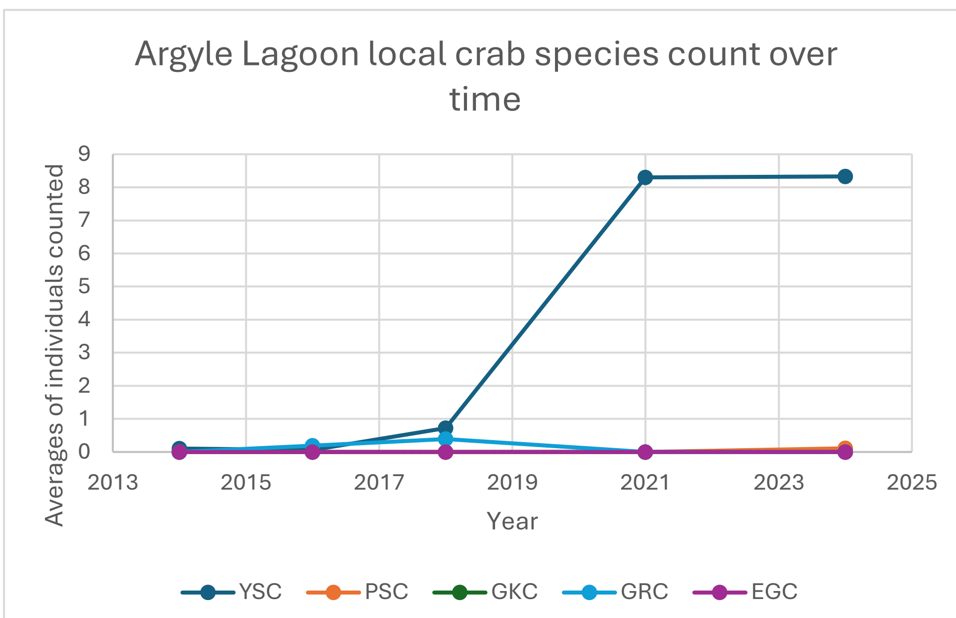

Figure 5 – The averaged crab species abundances at Argyle Lagoon plotted over time. All data points provided by previous surveys are plotted above.

Discussion

Overall, there was no significant difference in the shore crab species abundance from 2013 to 2024 on the San Juan Islands. YSC remained the most abundant species in both crab trap and quadrat surveys over the years. 96% of the crabs counted in this project were YSC, which was similar to the 2013-2021 count determining that 97% of the crabs counted were YSC. (Yamada, 201). **Combined with the absence of EGC in all surveys, this indicates that the shore crab population is in normal and in healthy conditions not yet greatly affected by climate change.** Compared to the data from previous research conducted by Yamada (2021), False Bay had relatively consistent crab abundance over time besides a decline in YSC. All crabs besides YSC tended to be consistently low in numbers throughout the years (Figure 4). YSC were observed to be declining between 2013 and 2021, and the results from 2024 support this downward trend. However, the decrease in YSC counted in 2024 the False Bay survey could be related to the differences in sampling methods and seasons from previous studies (Yamada, 2021). There was a significant difference found in crab species abundance between Argyle Lagoon and False Bay. This implies that there may different environmental conditions between the two mudflats that make it preferable for shore crabs. Since False Bay has a wide mid-high tide area of 150m compared to the 50m in Argyle Lagoon, the mid-high tide area could have lower wave exposure and lower water exposure. YSC are observed to prefer habitats with lower wave exposure and more mud, which should make False Bay preferable for these crabs (Oliver & Schmelter, 2018).

False Bay had more diversity in rock types and sizes ranging from rocky to fine mud, whereas Argyle Lagoon was consistently rocky (Figures 6, 7, and 8). Two samples were done at rocky sites, four samples were done at muddy sites, and three samples were done at sites that were mixes of the two types. Although YSC prefer sandier mudflats like False Bay over rockier mudflats like Argyle Lagoon, there was a higher average of YSC counted at Argyle Lagoon. This may be explained by mud-burrowing traits of the shore crabs. Shore crabs are able to bury themselves well in sand and mud, so crabs at sandy quadrats in False Bay may already have hidden when the quadrats were placed (Oliver & Schmelter, 2018; Visser et al., 2004). Therefore, it is difficult to draw conclusions about crab species abundance from sandy mudflat quadrats.

Using crab traps to record crabs that could be hidden in the sandier mudflats would provide a better estimate of their species abundance in this sediment type.

Figure 6 – A quadrat sample at False Bay on a rocky part of the beach. Two of the quadrats were taken at a rocky site.

Figure 7 – A quadrat sample at False Bay on a muddier part of the beach. Four of the quadrats were taken at a muddy site.

When testing for statistical significance between the data of the rockier quadrats in False Bay and the data of the quadrats in Argyle Lagoon, there was no statistical significance between the crab species abundances in the two sites ($p=0.43$). This means that this t-test would fail to reject the null hypothesis stating that there is no difference in crab species abundance between the two sites' rocky quadrats.

Figure 8 – A quadrat sample at Argyle Lagoon on a rocky part of the beach. All the quadrats were taken at a rocky site.

As climate change increases water temperatures and drastically changes shoreline ecology, understanding how mudflats change in response will be important to help sustain them (Dalton et al., 2013). As of this short-term survey in 2024, there have been no changes in crab species abundance and there have been no increases in EGC population. However, water temperatures will continue to rise and with that, the recruitment of EGC will become more likely to succeed. Combined with heat stress and the impending invasion of EGC, it is vital to understand the dynamics and compositions of healthy ecosystems. More thorough and long-term surveys investigating crab species abundances in mudflats with different environmental factors such as water exposure and heat stress are necessary. Thorough surveys can be done by adding more trials to the procedure and by doing surveys throughout the year. This would help scientists get a better understanding of ecosystem dynamics throughout seasons. Comparing crab species abundances between various ecosystems such as intertidal zones can provide more information on shore crab habitat type preference and how they evolve as their habitats change and competitors arise.

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