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Factors Affecting Distribution of Crab Species Within the Titlow Beach Marine Preserve: Carapace Size of Porcelain Crab (*Petrolisthes eriomereus*) Along a Six Meter Vertical Transect; Rehabilitation Capacity of Shoreline Organisms to Anthropologic Alterations

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Factors Affecting Distribution of Crab Species Within the Titlow Beach Marine Preserve: Carapace Size of Porcelain Crab (*Petrolisthes eriomereus*) Along a Six Meter Vertical Transect; Rehabilitation Capacity of Shoreline Organisms to Anthropologic Alterations

Cover Page Footnote

I am grateful for the assistance from Dr. Eliza Heery, Assistant Professor of Ecology in the Science and Mathematics Department of the School of Interdisciplinary Arts and Sciences at the University of Washington, Tacoma for providing us with the tools necessary to complete this research and for offering valuable feedback for its implementation and improvement. Thank you, also, to the research team with whom this project would not have been possible: Anderson, D. G., Gorichanaz, D., and Kindschy, K. J. Thanks also go out to the peers that took time and effort to review and provide feedback on this publication: Suprunyuk, D. (UWT), Nelson, K. (UWT), Benjamin, R. (UWT), Hoch, G. (USC), Jackson, M. H. (MD), and Selkin, P. (PhD).

Abstract

Tacoma, Washington's Titlow Beach, used as a bustling social resort in the early 1900s, a swimming hole until the mid-1900s, and a research-based beach-front-rehabilitation reserve in modern times, is considered an area in which anthropogenic alterations have caused significant impacts to marine life. In a benchmark study of Porcelain crabs (*Petrolisthes eriomerus*), specimens were observed at low tide to determine if there was a significant difference in carapace size versus distance from shore, as it was hypothesized that larger sized specimens would be located near the shoreline for thermal stress, predation avoidance, and egg release for mature females. Crabs were collected along the beachfront, at mean low tide, on April 30, 2025. Data that were collected for this study did not garner the results expected, that the average carapace size would increase as one descended toward the waterline. Very few direct comparison studies were found on the carapace distribution of crab populations within the Puget Sound region, making this study an important benchmark for current and future resource management purposes. The results put forth in this paper show there was no significant difference in average carapace size of Porcelain crabs from 0 meters to 3 meters along a 6-meter measured transect tape. A larger sample size, possibly of more than one species of true crab for comparison, would be ideal and would help to determine if the results from this study were accurately representative of size distribution of crabs amongst the intertidal zones of Puget Sound beaches.

Keywords: Porcelain crab, *Petrolisthes eriomerus*, carapace size, Puget Sound, fisheries

Introduction

Tacoma, Washington's Titlow Beach (Fig. 1), an area once pristine and teeming with a vast biodiverse ecosystem along its coastal shorelines, has, in the last decade or so, been classified as an area in which anthropogenic alterations have caused significant damage to the delicate ecosystems and the organisms within. Remnants of wharf pilings leaching contaminants into the locale (Fig 2; WSDE 2025), the Tacoma Smelter Plume (WSDE 2019), unregulated waste rock dumping from the now defunct Asarco Smelter (1890-1986) (Fig. 3; Will Hite Web 2025; Shannon and Wilson 2025), seawall armoring for railroad and residential constructs (WSDE 2025), and pollutants from heavy automotive traffic flow along the elevated Tacoma Narrows Bridge (Fig. 2; WSDE 2025) have caused significant changes in coastal processes and the health of the ecosystem of the Titlow Beach Marine Preserve. The damage is seen in shorelines by means of limited biodiversity and low population sizes of intertidal organisms habituating this ecosystem (Parks Tacoma 2025). The damage and pollution infiltrate the sediment pore space, tissues and cells of shoreline organisms, and vegetation of many Puget Sound beaches (Roy et al. 2024). This can lead to significant decline of intertidal marine life and may affect carapace sizes of crabs (Márquez and Idaszkin 2021) in comparison to those that have access to cleaner, less polluted shores (Chen et al. 2020); hence, the importance of this benchmark study, particularly within the bounds of the Titlow Beach Preserve research area.

The Pacific Northwest is one of the United States' top producers for commercial fish, shellfish and crabbing resources (Fig 4; Table 1); the most recent 2006 economic analysis states that this industry "supported an estimated 16,374 jobs and \$540 million

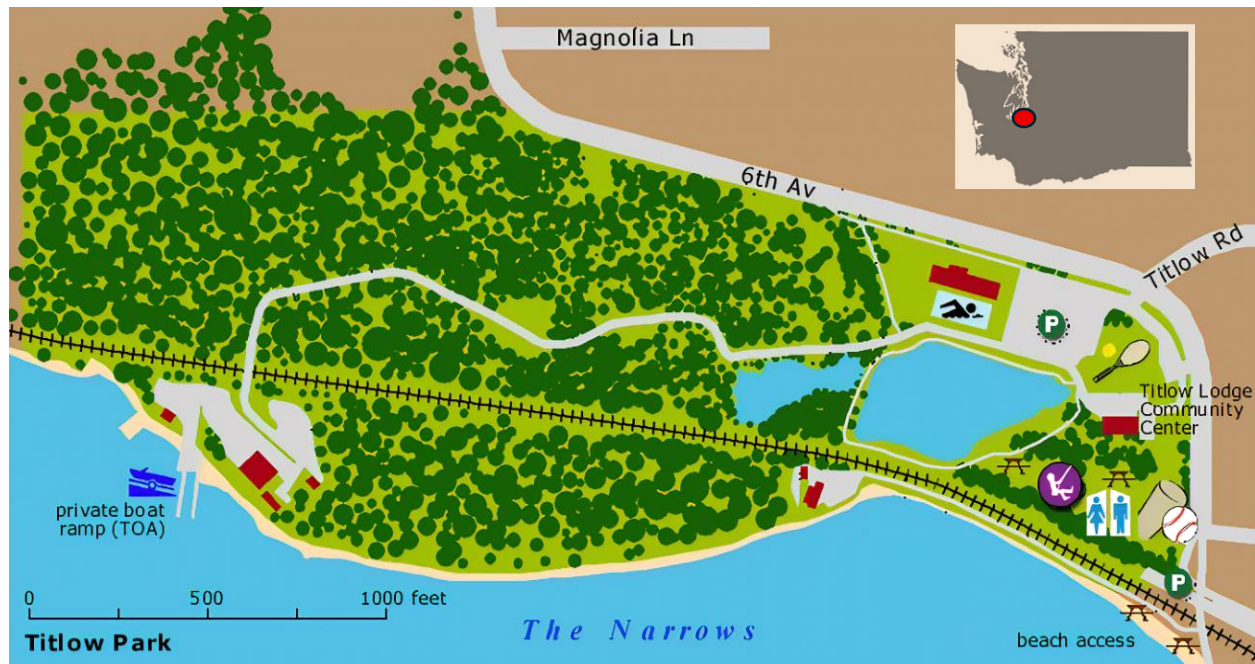


Figure 1. Titlow Beach as shown from an aerial view. The beachfront has been altered to support the transportation of goods via train along the West coast shorelines between Washington State and California. Often these trains transport coal, which is shipped in uncovered cars. When traveling at higher speeds, coal dust and particles are windblown from these cars and settle in local area soil and water systems (Parks Tacoma 2025)

in personal income...[when] viewed in the context of the Washington state economy, these levels of employment and earnings account for about four percent of total statewide employment and about two percent of total statewide personal income” (WDFW 2025); with 8,059,040 residents in the state of Washington (WPR 2025), two to four percent is a very large number of individuals/families supported by this, or other satellite, industries. Of this production, an estimated 21 percent originates from the crabbing industry with Dungeness (*Metacarcinus magister*), Red Rock (*Cancer productus*), and King crab (*Paralithodes camtschaticus*). These hard-shelled species provide the most meat: 25 percent of their body weight versus only 20 percent of “watery, mushy... or even ‘jelly-like’” flesh in soft-shelled crabs (WDFW 2025). Every year, the National Oceanic and Atmospheric Administration (NOAA) conducts bottom trawl surveys in the Bering Strait of these larger crab species to assess the distribution

and abundance by measuring metrics, such as “sexual maturity, disease prevalence, condition, and size” (NOAA 2022); this data is then used to further assess crab growth and reproduction to ensure population levels remain within sustainable ranges for future fishery and public necessity. Because one of the main staples of larger crab species are small shore crabs, knowledge and data regarding the distribution, abundance, gender, and carapace size of shore crabs are key to maintaining the supply/demand of the area’s economy and fisheries productivity. Pollutants, including high levels of mercury and/or fluoride, may also have a negative impact on revenue due to possible public health effects when consuming crab from these waters (Moore 1971; Taylor and Calabrese 2017). These pollutants can stunt the growth of juvenile crab species and are linked to smaller carapace sizes (Taylor and Calabrese 2017). Monitoring shore crab population health is one of the first defenses against larger economic and human health impacts.

Although most of the commercial fishing and crabbing occurs at the northern tip of Washington’s western peninsula, the Puget Sound inlet is an area used heavily by recreational and sport anglers (WDFW 2025). The beach profile of Titlow Beach, near the southern tip of the Puget inlet, follows a relatively standard subduction-zone profile (Fig 5); sedimentation grain size distribution is graded from large boulders at 0m to finer, sandier, sediment beyond the 6m measurement (~10m) was noted as one moves along the set transect. In addition, the Puget basin has a dual tide schedule due to the interactions of the sun, moon, and rebounding wave action (Fig. 6) at the inlet of the Sound (TTS 2025) which helps to create a standardized boulder/grain distribution along Tacoma area beachfronts; storm impacts are somewhat mitigated by the mouth of the

inlet. This means that the organisms found in this ecosystem must have evolved to hold some intrinsic defense mechanisms, or adaptations, that allow them to be more resilient to temperature, salinity, and other natural factor shifts than crabs in less static environments (Singh et al. 2021).



Figure 2. Titlow Beach Marine Preserve area with contaminated wharf piling remnants in the foreground of the photo. In the background of the image lies the outline of the Tacoma Narrows Bridge connecting the Kitsap Peninsula to the mainland of Washington State's Tacoma city limits (Briggs 2019)

These conditions led to the hypothesis that larger carapace width crabs would be found nearer to the waterline at the 0m transect (Fig. 7) demarcation rather than at the higher 6m delineation; larger boulders, rocks, and sediment would allow ample habitation spaces for crabs and other marine populations to settle and thrive. In addition, it was hypothesized that larger crab carapaces would be found nearer to the waterline to escape from desiccation, competition, and predation as well as for adult female crab

access to the water for the release of eggs for fertilization. The low tide on the date of collection was listed at ~-3.421 ft (WFY 2025). The study was conducted in late April, which falls within the bounds of the mating and egg release season of Porcelain crabs (*Petrolisthes eriomerus*) in the Puget Sound area. In addition, a visual observation of the beach shows that the vegetation of the beach profile is concentrated between the 0-1m section of the transect, which supports the hypothesis that nutrient access/consumption would occur closer to the waterline. This lack of available nutrients in the backshore section of the beach profile may be caused by the high levels of contamination found in the area (HWW 2025) but was not the focus of this study.

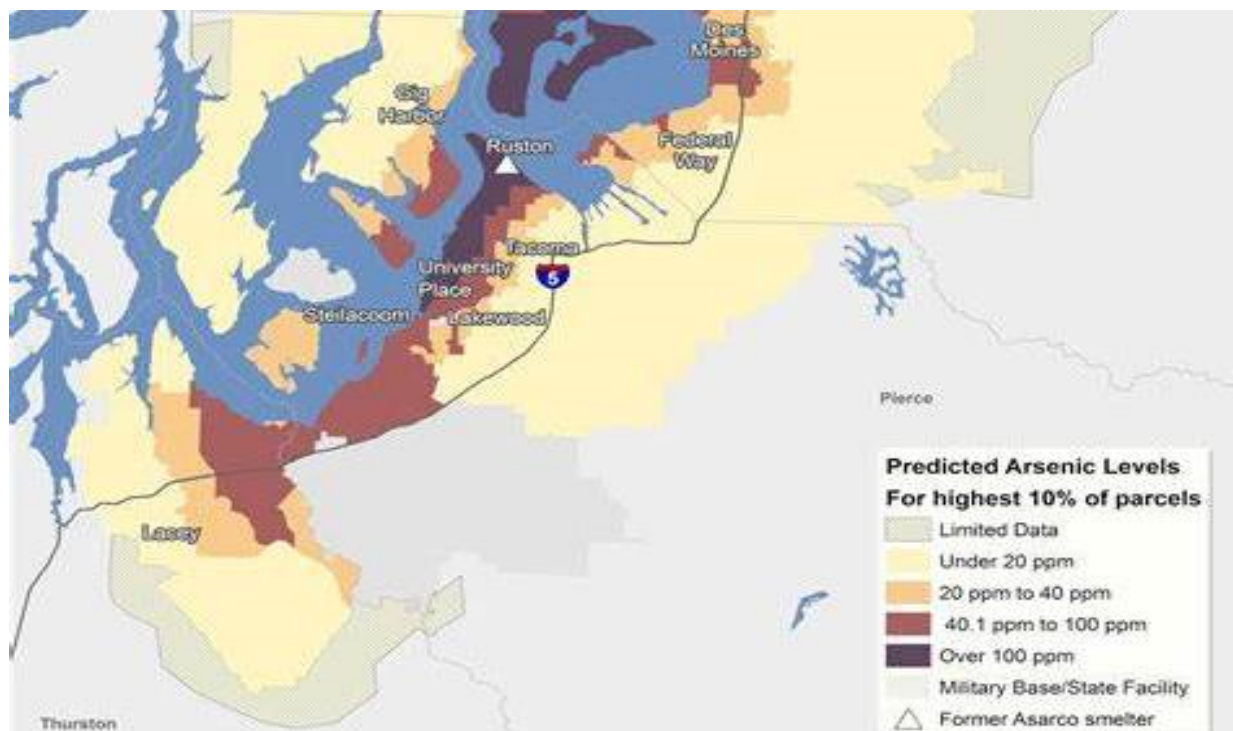


Figure 3. Arsenic levels in Puget Sound area soil from the now defunct Asarco Smelter Contamination Plume which leached into the surrounding area from runoff and unregulated waste rock dumping into the Puget Sound from 1890-1986 (WSDE 2025)

To mitigate the damage and to encourage the growth of biodiversity and population health of the marine organisms, the Washington Department of Fish and Wildlife converted the Titlow Beach recreation area into a Marine Education Reserve

(Parks Tacoma 2025). This allows the public to access waterfront recreational and educational opportunities while scientists continue to monitor and research the ever-changing shores of Washington State's Puget Sound. By collecting measurement data on the carapace size of Porcelain crabs from the lower intertidal zonation of 0m and 3m, researchers may be able to gauge the population size as competition interactions and habitation processes have shown that smaller zoea are present in a denser population level. It was also seen that when establishing a habitation zone, one alpha male Porcelain crab asserts dominance over lesser males, who are often permanently displaced and/or shunned by the larger male and the space in which it's claimed (Jensen and Armstrong 1991); Porcelain crabs are also seen to have an upper limitation of 3m and a lower limitation, determined by direct intra- and inter-species competition and depth of the water column, at roughly 0m (Patten 1977).

The purpose of this benchmark study was to determine whether the carapace size of Porcelain crabs correlated with the size of boulder distribution along a 6m transect moving up through intertidal zonation of Titlow Beach in Washington State's Puget Sound region (Shipman 2010). This would correlate with factors such as prevention of desiccation during tidal level shifts (Patten 1977), predation avoidance (Thirukanthan et al. 2023), competition (Jensen and Armstrong 1991), nutrient needs/access (Thirukanthan et al. 2023), egg release (Cowles 2025), and overall health of the environment in which they live, characteristics which are not addressed directly within this study yet play an important role in determining the distribution of a variety of crab populations of the region. Having data available from a benchmark study such as this can then aid local fisheries, recreational and sport anglers, and scientists in

maintaining healthy, consumable, and sustainable crab populations for future generations to enjoy.

Current Landings, Fishery Status, and Gear Deployment

Current landings updated: 2025-04-16 09:01:28.010168

Region	Status	Pot Limit *	Target **	Harvest	Remaining	Total Licenses	Total Vessels
1	Closed	0	1,796,507	1,472,775	0	0	0
2E	Closed	0	479,351	475,412	0	0	0
2W	Closed	0	157,199	160,079	0	0	0
3-1	Closed	0	7,491	40,442	0	0	0
3-2	Closed	0	236,609	238,071	0	0	0
3-3	Closed	0	13,410	12,454	0	0	0
3-4	Closed	0	2,605	2,609	0	0	0

Table 1. 2025 Target and Harvest numerical fisheries catch values for the month of April: groundfish account for roughly 0.61 percent of this value, and shellfish roughly 0.21 percent (WDFW 2025)

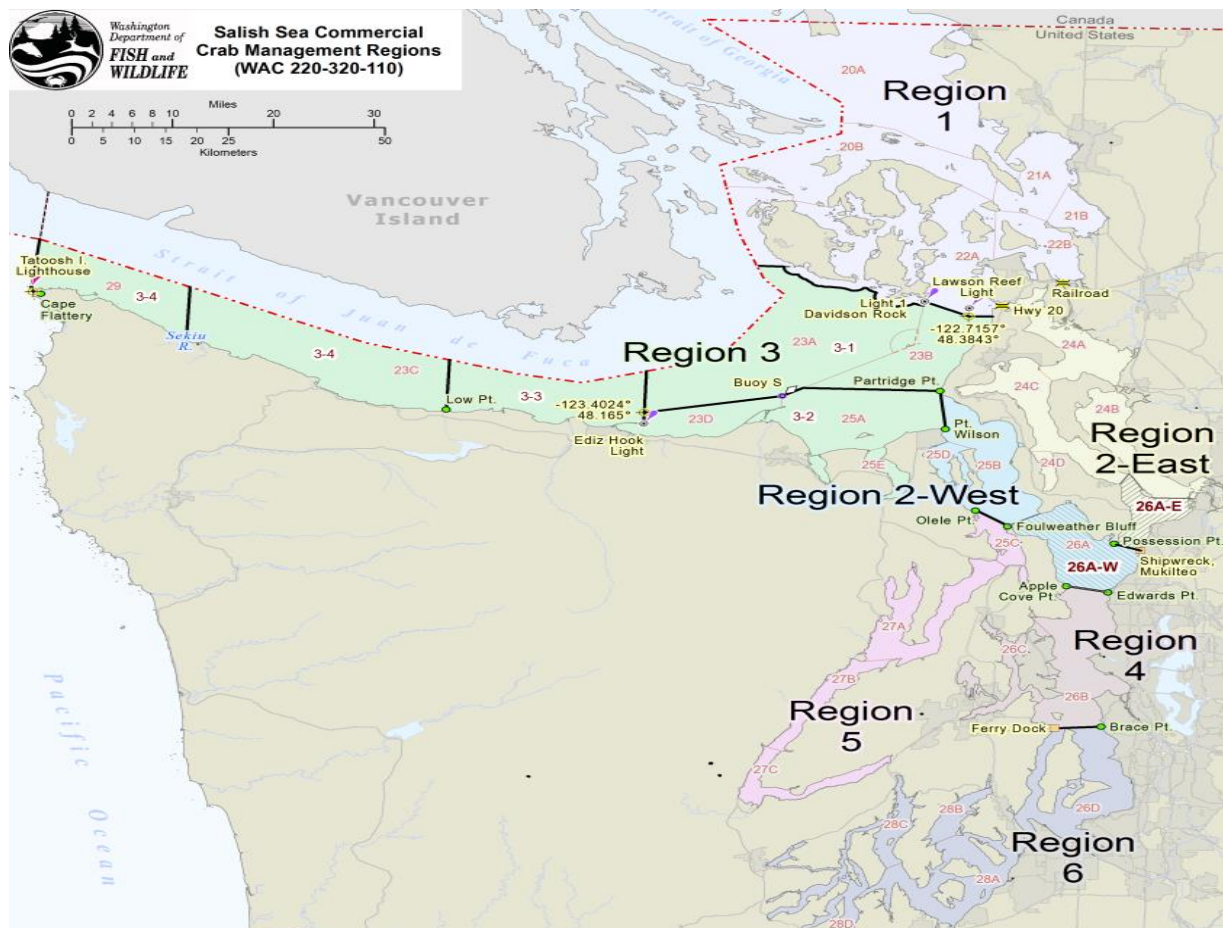


Figure 4: Washington State commercial crab (Dungeness, Red Rock, King crab) collection and management regions, 2025 (WDFW 2025)

Methods

Site Description

All crab specimens were collected at Titlow Beach Park (47.2470° N, -122.5530° W), located in the southeastern inner region of Puget Sound. Crab specimens were collected in situ on a clear, slightly breezy, 72° temperature day with $\sim 35\%$ cloud cover. Collected species found at the Titlow Beach location were: Red Rock crab (*Cancer productus*), Northern Kelp crab (*Pugettia productus*), Porcelain crab (*Petrolisthes eriomerus*), Yellow Shore crab (*Hemigrapsus oregonensis*), Black Clawed crab (*Lophopanopeus bellus*), and Hairy Helmet crab (*Telmessus cheiragonus*). Other species found in the local waters, but not located or used in this study, include Graceful

crab (*Metacarcinus gracilis*), Dungeness crab (*Metacarcinus magister*), Purple Shore crab (*Hemigrapsus nudus*), and others (WSU 2015; UW 2024).

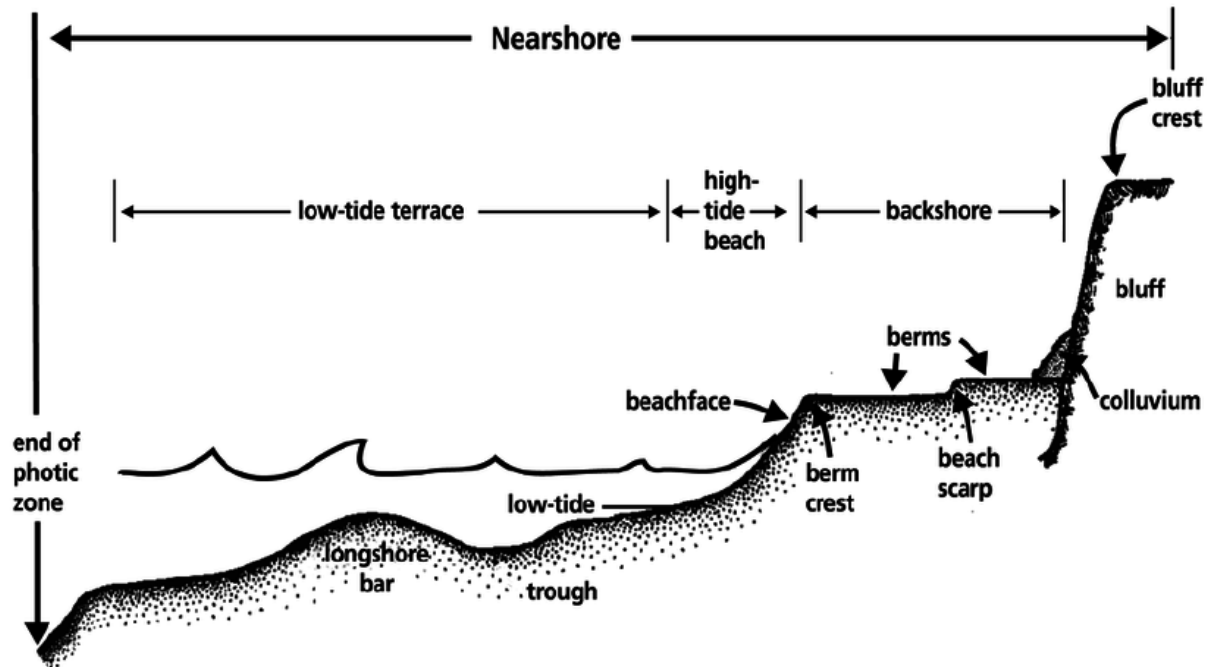


Figure 5. Typical Zones of a Beach Profile for subduction zone area based geologic settings found on the Titlow Beach Marine Preserve in Tacoma, Washington's Puget Sound region (Khorram 2018).

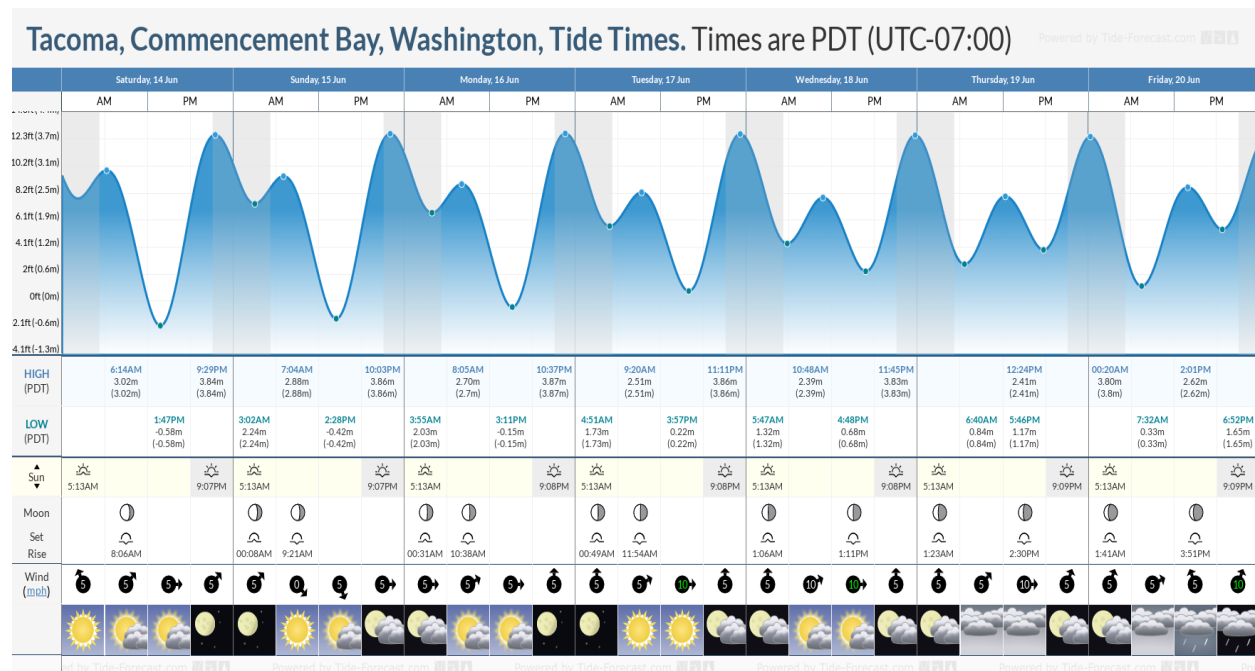


Figure 6. Typical late Spring tide schedule for Titlow Beach Marine Preserve, Puget Sound inlet, Washington State (TTS 2025)

Sampling Procedures

On April 30, 2025, between the times of 13:30 and 16:30, $n = 104$ crabs were collected by two groups, consisting of two observers each, which moved along a vertical transect. A transect is a 6-ft-plus measuring tape used to delineate measured research sections at 0m, 3m, and 6m (Fig. 7). Various crabs ($N = 104$) were collected during the low-tide period (13:30-15:30), from the intertidal zone, by hand flipping randomly chosen large and small rocks along a 6m transect. The rocks chosen were visually different in size; measurements were not taken, and data was not collected for this variable. Which rocks to overturn was decided upon in a complete randomization method between the two individuals working in tandem on the 0m, 3m and 6m collection sites at the time of the study. Specimens were collected into a 5-gallon bucket, using long BBQ-style tongs to protect both the experimenters and specimens, as quickly as possible when the rocks were displaced.

Measurement and Identification

When all the crabs from a rock divot had been collected, the species, size, and gender were determined (Fig. 8). In addition, key characteristics of carapace size (Fig. 9), shell coloration, and number of carapace teeth were referenced against iNaturalist (2008) and WSU Molt Search Crab Identification sheets (2015) to ensure correct identification of the species of collected crabs. The crabs were measured using a hand-held Vernier caliper (Fig. 10), and this data was handwritten onto the Data Collection sheets for each pair of scientists in the research team. This data was later copied into an Excel spreadsheet for ease of use in further computational analyses. After collection,

the crabs were returned to their natural environment and the rock replaced as carefully as possible so not to further disrupt or injure the marine life/ecosystem.



Figure 7: Stock photo of two researchers holding transect line at a rocky beach waterline. The tape is laid on the ground and boulders were removed to collect crab specimens from 0m, 3m, and 6m marks on the transect tape, as instructed in the pre-survey methodology. The transect is then moved along the beach to determine each study area (Unknown 2025)

Statistical Analysis

It was determined, due to the Porcelain crab being the only species found in the three-hour collection period which met the minimum sample size of 30 (at $n=42$), that this was the species of focus for the test; this decision was made amongst all four members of the research team, in the field, at the completion of the data collection portion of the experiment.

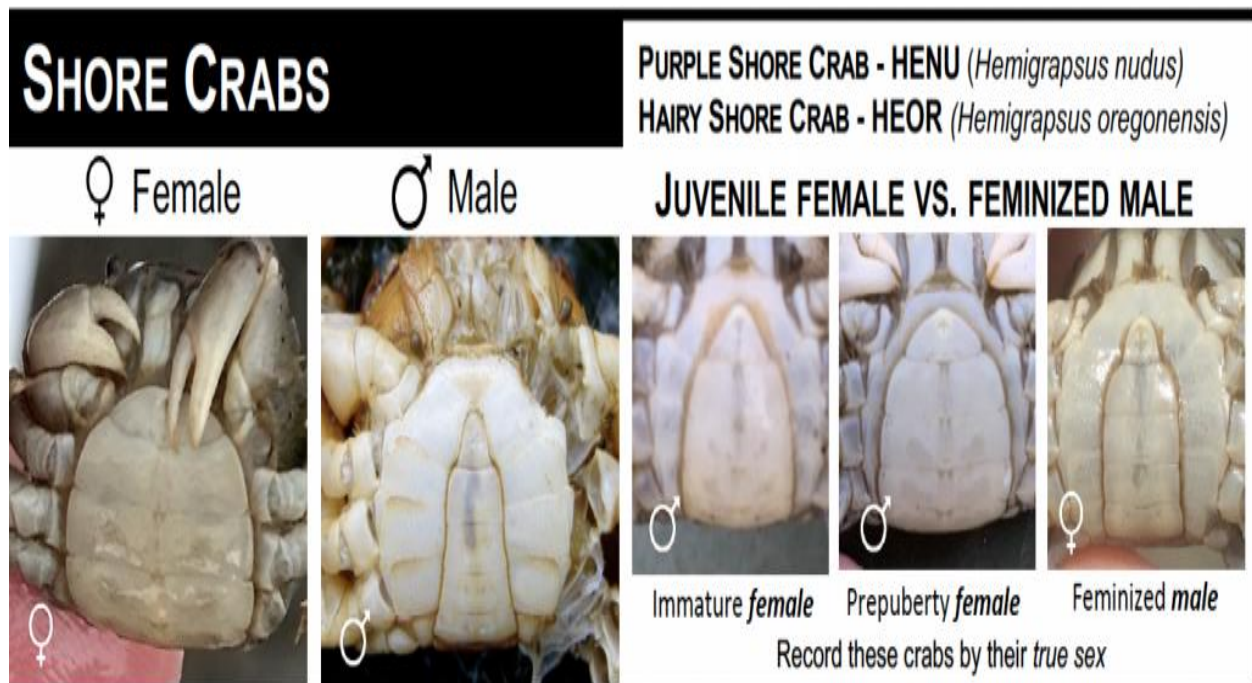


Figure 8. Gender of crab species can be determined by observing the Apron, or underbelly flap, of the crab. A female crab will have a wider, rounded Apron whereas a male crab presents with a thinner, pointed style of Apron flap (WSU 2015)

The compiled Excel data was then uploaded and further analyzed using the RStudio statistical application, which required the utilization of class exercises done previously in this coding and script language platform. First, all sample data collected was formatted to ensure that the organization was seamless and standardized, including the correct name, species identification and transect level associated with each data point. Next, the data was redacted to highlight only the species with the most prolific presence within the three transect measuring levels; it was previously determined that Porcelain crab had the most abundance and would be the focus of the study.

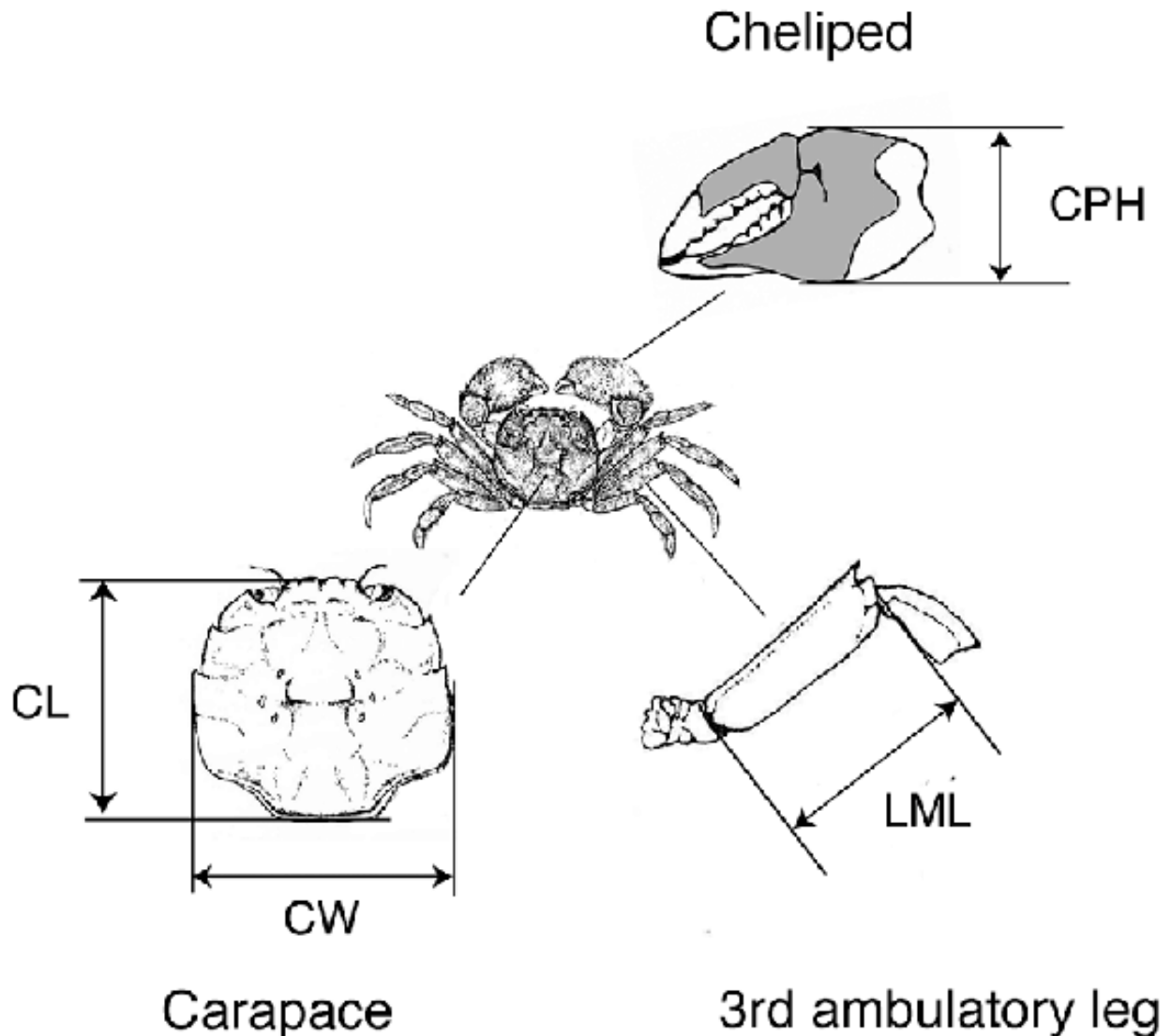


Figure 9. Proper location to place calipers to measure various parts of the crab anatomy; Carapace measurements are taken from the widest horizontal line in the Carapace using the Vernier, or other, caliper style measuring implement. CPH: Cheliped Height, CL: Carapace Length, CW: Carapace Width, LML: Merus Length (Kobayashi and Satake 2017)

As a result of this decision, data from the 6m transect was removed in its entirety as there were no Porcelain crabs located at this distance from the shore. The Porcelain crab data was then isolated from the rest of the crab species collected and used within the RStudio platform. The focus of the study (independent and dependent variables) was selected to be carapace size versus distance from shore to answer the initial hypothesis that distance from shore determines size of crab species due to access to

water, resources, and burrowing spaces: size of crab being a key metric for local fisheries and industry proponents.

A two-variable t-test was then run on the collected Porcelain crab data using scripted code within RStudio statistical analysis tool. This test was determined to be the appropriate analysis method after running assumptions of normality and equal variance, which was confirmed by conducting two Shapiro-Wilk normality tests on 0m and 3m of the researched transect. In addition, a Levene test for homogeneity of variance (center = median) was conducted as proof for the two-variable t-test analysis. The data was then compiled into this research paper along with graphs and tables to further support the textual data.

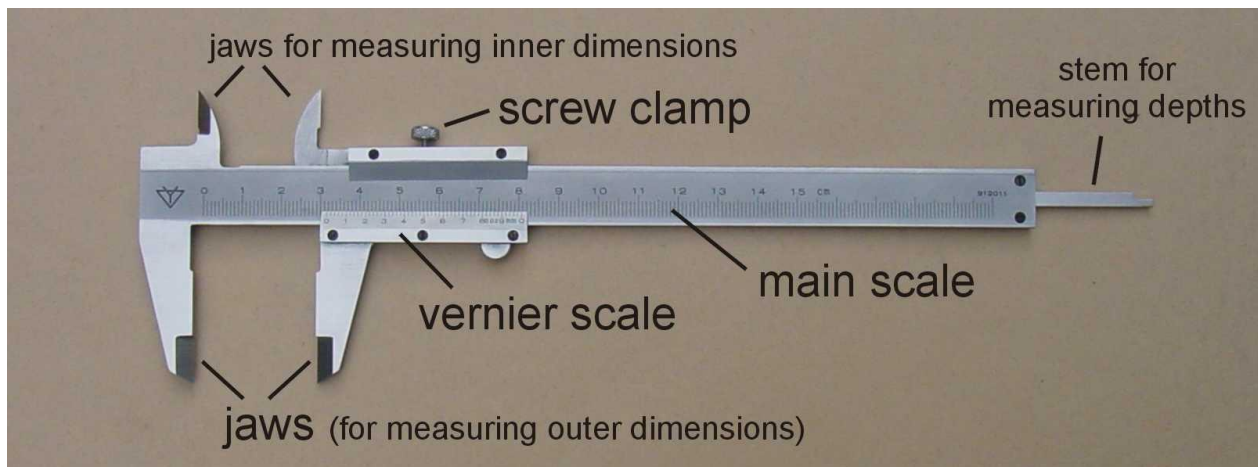


Figure 10. Components of a Vernier caliper used to measure carapace width of collected crabs for this study (MiniPhysics 2014)

Results

The species, size, and gender data that were collected from the rock turning study taken at Titlow Beach, Washington state on April 30th, 2025, did not garner the results that were expected. To confirm accuracy of this raw data, analysis using RStudio was used to return calculated p-values to determine whether to fail to reject, or outright reject, the null hypothesis. When the raw data was run through RStudio the resulting p-

value was found to be 0.593. This was not significant enough to confidently say that the carapace size of Porcelain crabs was distributed in a gradient along the transect, with larger sized crabs closer to the 0m intertidal water line. The overall very high p-value meant that we failed to reject the null hypothesis as opposed to rejecting the null hypothesis were the p-value to be less than 0.05.

The null hypothesis stated that there was no significant difference to be found in the carapace size of Porcelain crabs from 0 meters to 3 meters along a 6 meter transect. Assumptions of normality and equal variance were met, as confirmed by two Shapiro-Wilk normality tests on 0m ($W = 0.98355$, $p\text{-value} = 0.8761$) and 3m ($W = 0.94669$, $p\text{-value} = 0.5892$). A Levene test for homogeneity of variance (center = median) produced results of $Df = 44$, $F\text{ value} = 16.448$ and a $Pr(>F) = 0.0002011$ (Table 2). This determined that a Welch 2-variable t-test was the most appropriate test in which to analyze the collected sample data pertaining to the carapace difference in Porcelain crabs along the (0m) and (3m) vertical transects. When coded into RStudio, the two-sample t-test to compare size of Porcelain crab carapaces returned $t = 0.54883$, $df = 12.13$, $p = 0.593$.

Distance From Shore (m)	Crab Species	Number Observed	Female	Male	Average Carapace Length (mm)
0	Black Clawed Crab	6	6	0	14.33
0	Porcelain Crab	34	34	0	11.46
0	Northern Kelp Crab	1	0	1	20
0	Red Rock Crab	1	1	0	144
3	Black Clawed Crab	11	5	6	12.67
3	Porcelain Crab	12	9	3	10.77
3	Northern Kelp Crab	1	1	0	10.5
3	Pacific Hairy Helmet Crab	1	1	0	9.9
3	Yellow Shore Crab	7	3	4	16.77
6	Pacific Hairy Helmet Crab	3	2	1	7.63
6	Red Rock Crab	5	3	2	107.86
6	Yellow Shore Crab	22	11	11	14.5

Table 2: Raw data analyzed in Excel using the AVG function shows that there is a slight carapace size difference from the lower intertidal zone (0m) to a higher intertidal zone (either 3m or 6m) for each crab species collected.

Discussion

Initially, it was hypothesized that larger carapace dimensions would be found closer to the water, at 0 meters for this study. Although the initial raw data (Table 2) suggested otherwise, there was not enough difference to be confident that in all crab species this would be the results found from any given data collection event. To overcome this uncertainty, one would need to have a larger sample size, of possibly more than one species of true crab for comparison studies, to determine if the results from this study were representative of the complete population of crabs amongst the intertidal zones.

Very few direct comparison studies were found on the carapace size distribution of crab populations within the Puget Sound region, making this study an important benchmark for current and future resource management efforts in the Titlow Beach Marine Preservation area. Most conservation efforts within the preserve, and the Puget Sound inlet, revolve around local salmon and the impact these declining populations have on resident orca pods of the Salish Sea locale (NOAA 2025). However, it is important to note that conservation efforts that focus on the broad ecosystem have been shown to be more successful in terms of rehabilitation than those that are focused on one singular organism or natural beach characteristic (Des Roches et al. 2022). Carapace size of crabs may show population density and/or abundance within an ecosystem (Towne et al. 2023) as well as smaller crabs being prone to differing predation patterns, which may influence their survival strategies or predation susceptibility (Vermeiren 2023). Having a beachfront that is free of pollutants, invasive flora/fauna, and negative anthropogenic effects will allow for a higher abundance of

biodiversity and possibly a more distinct intra- and interspecies gradient in size of crabs of the intertidal zones of the Pacific Northwest.

Porcelain crabs are not scientifically classified as a true crab, rather a close relative of a hermit crab, and belong in the family Porcellanidae (MBA 2025). They grow to a maximum carapace size of roughly 25 cm as a species (Jensen and Armstrong 1991) and “have only 3 pair of walking legs (4th pair small and rudimentary) where[as] true crabs have 4 [walking feet]; porcelain crabs lack a wrist segment (carpus) on its claw appendage; and porcelain crabs have very long antennae vs. very short in true crabs” (Bowling 2025). In retrospect, this species was a poor choice for the benchmark study in the variability of carapace size distribution; this information should have been vetted in the initial research process. Due to this oversight, repeating this study using a species of true crab, such as the Kelp, Yellow, or Red Rock crab species identified in the data collection process, may produce a more accurate representation of a difference of crab carapace sizes from the shoreline up along the intertidal beach profile at this specific beachfront.

In addition, there was interference in the study that, if repeated, may result in more accurate representation of the carapace size of all crabs found along a 6m transect. At the time of collection, three individuals entered the study area and removed crabs from the lower intertidal zone, removing them from assumed aerial predators and/or other anthropogenic harassment/stressors. The individuals moved out of the transect area sooner than any one of the researchers were able to approach and explain the purpose of the visit during the study, and the study continued with the interference noted. It is not known the species, measured carapace size, or gender of

the crabs removed from their original locations; it was observed that a total of 6 crabs were removed from the 0m delineation of the transect. A better cordoned off transect area would limit this interference in further testing events.

Conclusion

Using data collected in this benchmark study, local scientists, conservationists, fisheries, and/or other agencies can better manage and distribute the natural resources of the Puget Sound region. Collecting shore crab size and gender data, combined with an understanding of the trophic interactions of crabs in intertidal zones, will allow industries to better gauge catch limits and the possible need for additional farming facilities to meet the public supply and demand for shellfish products originating from the Pacific Northwest. Further studies are needed to fully understand the specific triggers that aid, or limit, carapace growth in shore crabs; this could ultimately bolster production levels of larger, more consumable species of crabs if populations of intertidal crabs are allowed to grow and thrive in areas free from pollutants and/or other anthropogenic impacts.

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