HANDLE WITH CARE: ECOLOGICAL AND ETHICAL IMPACTS OF HANDLING *CRYPTOCHITON STELLERI* IN THE INTERTIDAL

by

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Gumboot chitons (*Cryptochiton stelleri*) are grazers in the rocky intertidal, where their feeding behavior and strong site fidelity may influence algal composition and community structure. Individual chitons are frequently handled by scientists, students, and the public, yet the physiological and ecological consequences of such interactions–which may disrupt their microhabitat occupation, feeding rates, or attachment ability, resulting in mortality or broader ecological shifts–remain largely unstudied. This project seeks to characterize the microhabitat occupation of *C. stelleri* at three sites along Cape Arago in Coos Bay, Oregon and investigate the effects of human handling on their feeding rates, attachment ability, and righting ability in a laboratory experiment. I used Uniform Point Contact surveys to quantify the benthic community in a 1m^2 area associated with n=21 chitons in the field in combination with laboratory trials to quantify behavioral changes following handling. Handled chitons displayed significantly lower feeding rates and longer time spent righting and reattaching than unhandled control chitons. These results suggest that handling *C. stelleri* affects their behavioral ecology, necessitating the consideration and management of human-animal interactions in intertidal ecosystems. This study also merges the fields of ecology and ethics, exploring the experimental data through a philosophical lens and proposing methods for ethical experimentation through a pragmatist and kincentric framework. Taken together, these experimental results and ethical considerations highlight the importance of weighing the scientific benefits of hands-on interaction against possible impacts, advocating not for the elimination of handling but for more deliberate, ethically informed approaches to working with marine invertebrates.

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Finally, because this is an ethics project, I offer a final thank you to the Oregon coast, to the organisms I encountered as a marine biology student, and to the gumboot chitons of South Cove, Lighthouse Beach, and Sunset Bay. Thank you for letting me learn with you. It is a gift I hope to repay through my work and continued kinship.

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Introduction

Gumboot chitons (*Cryptochiton stelleri*, Middendorff, 1846, Polyplacophora: Mopaliidae) (Figure 1) are not only important algal grazers but also large and charismatic macroinvertebrate individuals in the intertidal (Figure 2) that draw the attention of visitors and scientists alike. These mollusks inhabit rocky intertidal and subtidal areas along the Pacific coasts of the Northern Hemisphere, often occupying microhabitats or niche areas within larger sites to protect themselves from predation and environmental harshness (McIntire & Bordeau, 2020; Lord, 2011). During my time participating in fieldwork on the Oregon coast, I've observed students, scientists, and members of the public often handling gumboot chitons in the intertidal, prompting me to question the physiological and ecological impacts of such interactions. Handling these large and easily recognizable organisms seems to be an effort to better understand them, yet it raises ethical and ecological concerns. I aim to reflect on the balance between the benefits of interacting with organisms in their natural environment to foster understanding and protection versus the potential detriments to the organisms themselves. Is such handling justified if it causes harm, and is it still justified if the harm isn't readily recognizable or scientifically observable?

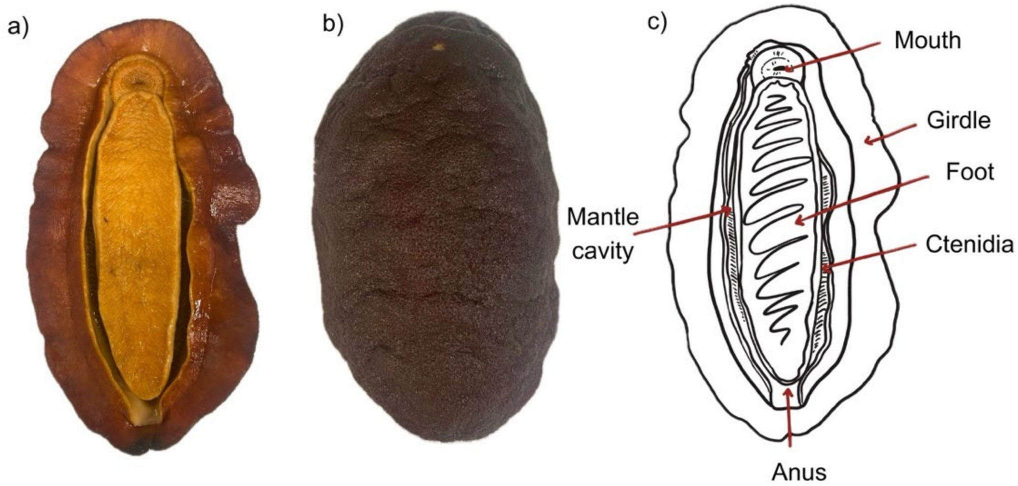

Figure 1. External morphology and anatomy of *C. stelleri*. a) ventral view b) dorsal view c) schematic with labeled anatomical structures.

Figure 2. Gumboot chiton in the intertidal.

I often find that my field of study strives to protect the environment and the organisms within it, yet it sometimes overlooks the short-term, localized impacts of research practices. Even as we seek to better understand how to protect environments like the rocky intertidal, these spaces and the organisms inhabiting them experience mortality and disturbance from our actions. The ethical implications of this work remain an interesting yet often overlooked topic. Furthermore, perspectives from Indigenous and other non-Western philosophies, which often emphasize interconnectedness and respect for living beings, offer valuable alternatives to the research practices that create these ethical dilemmas.

My specific contribution to this field of study will be to examine the effects of handling gumboot chitons, a topic that is rarely addressed in invertebrate research, by combining experimental data with a dedicated ethical analysis. Specifically, this research will focus on the physiological and ecological effects of handling, including impacts on microhabitat occupation, grazing rates, and mobility, as well as the potential ethical consequences of such disturbances. These localized effects, while significant, also reflect broader concerns about how other, similar human activities such as collecting or trampling—whether intentional or incidental—affect marine ecosystems by altering community structure and reducing diversity in the ecosystem (Addessi, 1994). Addressing these issues invites important ethical discussions about the responsibilities of researchers and society in minimizing harm while fostering scientific understanding.

To better understand the potential impact of hands-on interactions with gumboot chitons, it is necessary to understand their ecology. Intertidal gumboot chitons have a patchy distribution that seems to be partly due to microhabitat selection in addition to larval recruitment dynamics and strong site fidelity (McIntire & Bordeau, 2020; Lord, 2011). The patchy distribution of gumboots, with clumps of adults in concentrated areas, may impact local algae density (Lord, 2011). Given their grazing patterns and their large size, disturbance that affects *C. stelleri* density or ecological function has the potential to alter the intertidal ecosystem ecology, particularly on a localized scale. Wave action (which may cause dislodgment) and temperature are two of the significant factors discussed in the literature relevant to determining the microhabitat selection, and therefore ecological role, of intertidal gumboot chitons (McIntire & Bordeau, 2020; Yates, 1989). Gumboot chitons are also common in shallow subtidal habitats, increasingly so near the southern parts of their range on the Pacific coast, but less is known about the habitat association and ecological dynamics surrounding the species outside of the more accessible intertidal. Generally, in subtidal habitats, the species exhibits higher activity and larger home ranges, as submerged habitats may provide a refuge from wave shock and the environmental harshness of the intertidal. Additionally, the impact of grazing on algal composition may be more restricted at intertidal sites due to this lessened activity as compared to the subtidal (Yates, 1989). In this thesis, I will examine and interpret the implications of handling intertidal gumboots in particular.

Intertidal gumboot chitons may select microhabitats based on wave action as this environmental factor influences their foraging and attachment behaviors. Firstly, wave-heavy areas may not be conducive to their survival, with dislodgement from wave action being a significant source of mortality (Yates, 1989). Gumboot chitons in wave-heavy environments are also less active, exhibiting reduced grazing rates. Additionally, wave action may also impact the presence of algae in an area, as wave-swept areas are too harsh to allow the growth of the leafy bladed algae *C. stelleri* feeds on (Yates, 1989). Physical structures within the intertidal, such as rock and boulder-covered microhabitats, provide chitons with protection from wave action, and larger chitons are often found in these areas (Mercegue et al., 2021). *C. stelleri* in particular are also often found in crevices and cracks and exhibit a preference for this rocky substrate (Yates, 1989).

Wave action also influences habitat selection and distribution by affecting movement patterns. Gumboot chitons tend to occupy very small home ranges, potentially limited to 6 square meters over 300 days (Yates,1989). This limited movement creates a strong association with specific sites, which may help reduce energy use and minimize exposure to predators (Lord, 2011; Yates, 1989). Chitons moving through high-wave areas also risk dislodgement due to their decreased attachment ability while moving, leading them to favor sheltered microhabitats (Lord, 2011).

Temperature is another important cue that gumboot chitons respond to when selecting a suitable microhabitat. Response varies between populations, with chitons from warmer climates preferring sheltered microhabitats to avoid direct sunlight, while those from cooler climates prefer exposed surfaces. In a lab setting, gumboots tend to select microhabitats that allow them to achieve body temperatures 3°C below their optimal temperature of 20°C in air and 18°C in water, above which grazing and respiration rates dramatically decrease (McIntire & Bordeau, 2020). In both lab and field experiments, chitons exposure to air demonstrated significantly reduced activity and feeding rates than submerged chitons (McIntire & Bordeau 2020; Yates, 1989). Given the apparent reliance on microhabitat selection to maintain optimal body temperatures and the effects of air exposure on temperature, handling a chiton, exposing them to air, and removing them from their microhabitats may impact their body temperature and ability to thermoregulate–subsequently altering grazing rates.

While gumboot chitons demonstrate preferences in the types of algae they consume, with *Mazzaella sp*. being the most preferred species of those tested, they are also generalist foragers in the field and graze on the most abundant algae in a given area (Yates 1989). *C. stelleri* primarily consumes red algae, including *Mazzaella* sp., *Cryptopleura* sp*.,* and some green algae including *Ulva* sp. *(*Yates, 1989). This adaptability indicates that, although food availability shapes feeding preferences, it is not a primary factor in distribution or choice of microhabitat for gumboot chitons (Yates, 1989; Lord, 2011).

The species' limited mobility, strong site fidelity, large size, and generalist feeding habits may position the species as a significant grazer in the intertidal, potentially influencing algal composition, although further study is required in this area to determine the direct impact of *C. stelleri* on algal composition and community structure. While it is known that herbivores such as gumboot chitons may have strong effects on the distribution and community composition of algae, algal density in the intertidal may also be subject to ecological and trophic relationships that are not yet well understood. In addition the influence of trophic cascades, the overlap of various intertidal algal grazers' preferred food sources may mean that the presence or absence of one may significantly affect the presence of another in an "indirectly mutualistic" fashion, a phenomenon described in other marine herbivores (Dethier & Duggins, 1984).

The lack of food-driven distribution patterns discussed above further supports the idea that gumboot chitons select microhabitats in response to physical factors such as wave action and temperature. Handling may disrupt these environmental relationships by exposing individuals to air or removing them from thermodynamically favorable or wave-sheltered habitats, which could affect how they live and feed in their environment. Additionally, handling itself may impose direct physiological stress. Such disturbances could reduce attachment ability or alter grazing behavior, leading to potential energetic costs and ecological consequences. The microhabitat selection of these chitons is influenced by and subject to many factors, many of which are not fully understood, requiring more study–especially in the context of human disturbance and changing microhabitats.

This study investigates the behavioral changes following handling and the ecological patterns of *C. stelleri* by utilizing both experimental trials and field observations. Specifically, I assess whether handling affects feeding rate, attachment ability, and righting ability through laboratory experiments—metrics related to ecological distribution through microhabitat occupation, ecological function, and survival. I also examine the types of microhabitats gumboot chitons occupy in the field. Using this approach, I aim to clarify the effects of handling under controlled conditions and provide baseline ecological data on microhabitat occupation.

This research serves as a foundation for future studies that could directly link and quantify human participation in ecology through handling, helping to clarify how localized, small-scale human–animal interactions in the intertidal may affect this species.

Methods

Multi-site quadrat surveys

To investigate the microhabitat occupation of gumboot chitons, quadrats were set up along the 0.5m tide height (using the projected low tide as a reference) at each of three sites: South Cove, Lighthouse Beach, and Sunset Bay, all of which are located along Cape Arago in Charleston, Oregon (Figure 3). Other researchers and I walked along this 0.5m tide height and located 12 chitons at each site. Sampling typically required two visits per site, ideally at similar times of day to control for environmental variables. On the second visit, we moved further out from the site access point to avoid resampling the same individuals if they were not collected during the first visit. Due to tidal timing and the presence of high wave action during the fall of 2024 on the Oregon coast when the experiment occurred, it was often not feasible to obtain microhabitat data for each chiton encountered in the field. On these occasions, the first chiton encountered in the area was used for microhabitat analysis, and the others in the area were collected for laboratory experiments. The presence and number of these other collected chitons in the area were noted.

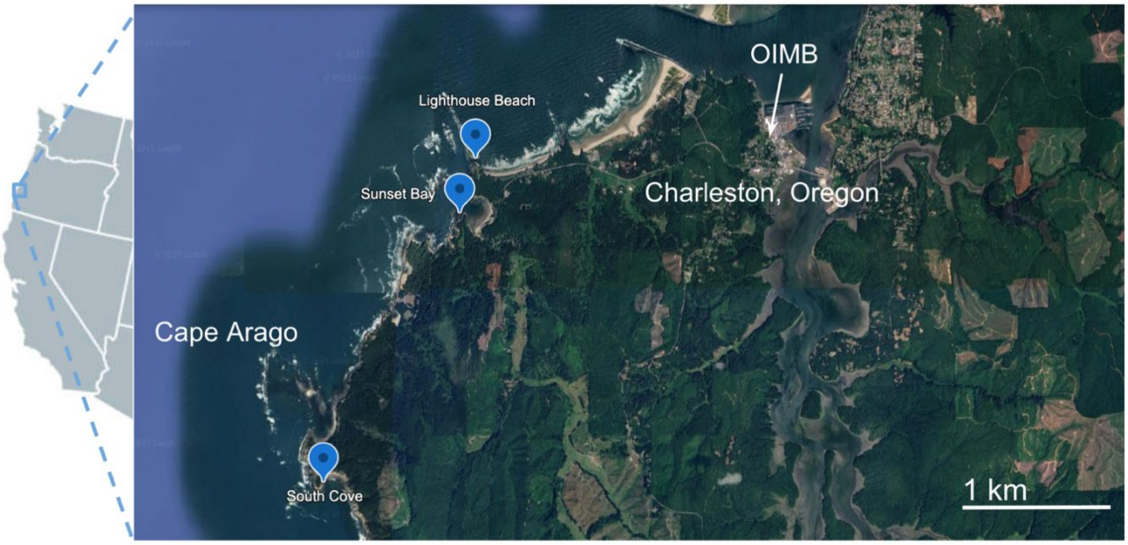

Figure 3. Map of collection sites.

Upon locating a chiton in the field, we centered four 0.25m² quadrats around it, forming a 1m² sampling area. If multiple chitons were present within the same 1m² area, only one was sampled, while the presence of others was noted. Data on microhabitat features such as crevices, overhangs, exposure, and percent water cover were recorded on a data sheet for each 1m² area. Uniform point contact (UPC) data were collected at each of the 64 crosshairs within each 1m² quadrat. At each point, the substrate type (rock, sand, or cobble), presence of algae, and other organisms (based on a marine species list developed by Dr. Aaron Galloway for his Marine Ecology course, adapted from the research network data system DIMES: Diversifying and Integrating Marine Education at Stations) were recorded (Table 1). Biological codes, or those excluding substrate (hereafter referred to as taxa), included functional groups, genus complexes, or genus/species identifications. A photograph of each quadrat was taken, and the body length of each chiton was measured from its anterior to posterior end. The rugosity within the quadrat was recorded using a rugosity index, measured by laying flexible nylon rope ½ inch in diameter and 1m in length following surface complexity through the 1m² quadrat area perpendicular to the water line. The actual distance covered by the rope was recorded. To calculate a rugosity index value, the length of the rope was divided by the actual distance covered when following surface contours. After completing quadrat sampling, each chiton was collected in a bucket for transport to the laboratory.

Tagging Procedure

In the laboratory, each chiton was tagged following an approach modified from Lord (2011) in which a colored zip tie is inserted through the girdle of each chiton (Figure 4). To attach the zip ties, I pierced the chitons' girdles with a 16-gauge needle and inserted a small, colored zip tie through the hole. To minimize harm, the zip tie was left slightly loose and the tagging procedure was completed as quickly as possible. All collected and tagged chitons were monitored until they reattached and then kept in a sea table with flowing seawater and four oxygen bubblers to ensure high oxygen concentration in the water. The circulating seawater in the sea table is pumped in from the mouth of Coos Bay at high tide, meaning that the water chemistry and conditions likely match the natural conditions of the chitons' habitat. I waited 24 hours from tagging before the start of any lab experiments and tags were removed at the end of the study before returning the organisms to the intertidal. During the tagging procedures, the chitons rolled into a ball (a characteristic behavior of the species), unrolling and resuming mobility usually within two after hours after tagging. No immediate or direct negative effects of the piercing process were noted.

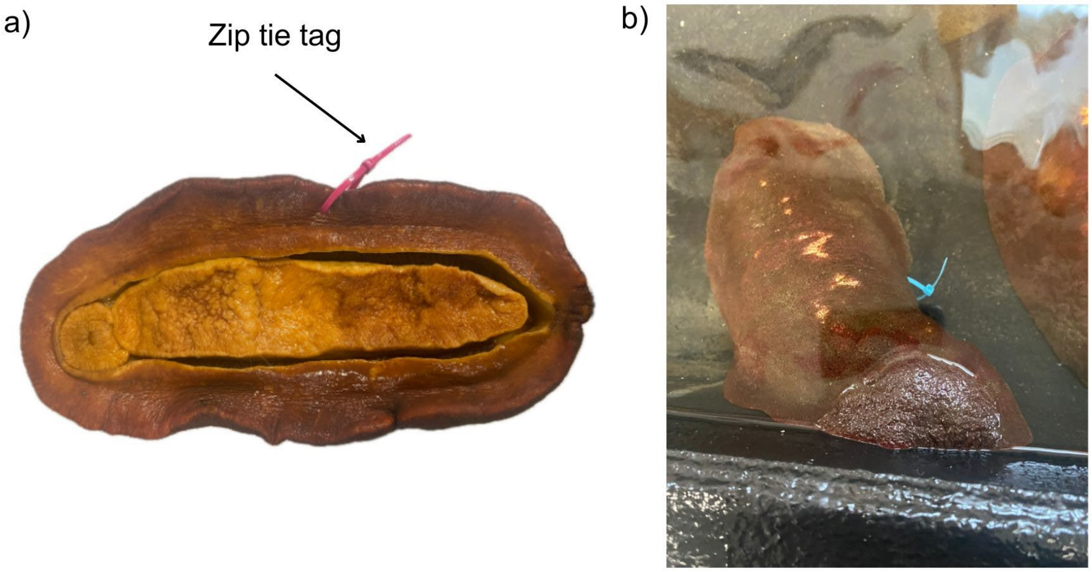

Figure 4. a) Ventral view of a tagged chiton. b) tagged chiton in the sea table.

Feeding rate measurement

To assess the feeding rates of chitons, two individuals were randomly selected for each trial and randomly assigned as either "handled" or "unhandled." Both chitons were dislodged from the sea table and placed in separate shallow bins submerged in the sea table that allowed water flow via holes in the sides and included air bubblers. They were given thirty minutes to reattach and acclimate in these bins. During this acclimation period, approximately 20g of *Mazzaella sp*. (collected at the sites where the chitons were found and stored in a bucket in the sea table) was blotted dry, weighed, and the weight to be given to each chiton was recorded. 20g was chosen because it allowed sufficient excess algae for the chitons to eat ad libitum, or as much as desired without limitation.

After the half-hour acclimation period, the designated handled chiton was held above water for 10 minutes. During handling, the chiton was occasionally pried open if it exhibited rolling behavior, with light motion introduced to mimic common handling behaviors that might occur in intertidal zones. After handling, the chiton was placed with its ventral side down to prevent any need to right itself. Each chiton was provided with seaweed in the submerged bin. The feeding trial began at 8:30pm, and the chitons were left overnight with water and air flow maintained, while overhead lights were turned off, as *C. stelleri* are nocturnal grazers (Alaska Department of Fish and Game, 2006).

The following morning, at 8:30am (12 hours after the feeding trial began), the algae was removed from the bins, blotted dry, and weighed. The difference between the starting and final weight was recorded to determine the amount of algae consumed by each chiton. The chitons were then removed from the bins and returned to a general holding area without food to minimize differences in feeding rates due to hunger. This experiment was repeated for all chitons, allowing each chiton to undergo both handled and unhandled conditions, with at least a 24-hour period between trials to avoid cumulative effects of recent handling.

Reattachment ability time trials

For reattachment trials, two chitons were randomly designated for each experiment, with one assigned to be handled for 5 minutes and the other for 10 minutes. During handling, the chitons were held above water and were occasionally pried open if rolled up. Gentle motion was also introduced to replicate intertidal handling conditions. After the designated handling time, the chitons were placed ventral side down in a bin to prevent righting behavior and its potential effect on reattachment time. A stopwatch was started immediately, and the time required for each chiton to fully reattach its foot and form its girdle to the bin surface was recorded. This protocol was repeated for all chitons, with each individual experiencing both lengths of handling time, with at least a 24-hour gap between trials to mitigate any cumulative effects of handling.

Righting ability time trials

For each righting time trial, two chitons were randomly selected and assigned either to the "unhandled" or "handled" group. The unhandled chiton was dislodged from the sea table surface and immediately placed ventral side up in the submerged bin near the corner, ensuring that its posterior end and one side touched the bin wall to cue righting behavior. The second chiton was held above water for 10 minutes according to the handling protocol discussed in the section above on attachment ability. Following this handling period, the chiton was placed ventral side up, with at least one side and posterior end touching the wall of the bin to cue righting behavior.

The time taken by each chiton to fully right itself, with all parts of the girdle touching the bin surface, was recorded. If a chiton remained in a "ball" position for more than 30 minutes without attempting to right itself, it was removed from the bin, placed ventral side down in the sea table, and a "Did Not Finish" (DNF) was recorded on the data sheet. This experiment was repeated with all chitons, with each individual undergoing both the handled and unhandled conditions, separated by a minimum of 24 hours to minimize cumulative effects of handling.

We analyzed the effects of handling on *C. stelleri* feeding, attachment, and righting using a linear mixed model for each experiment, with handling status as the predictor and feeding rates (g/hour), attachment time (s), or righting time (s) as the outcome variables. We included individual chiton identity as a random effect to account for repeated measures. Statistical significance was assessed using alpha=0.05.

Results

Ecological Surveys

Substrate Composition

Uniform Point Contact surveys showed that *C. stelleri* habitat was dominated by rock substrate across all three sites (Figure 5). The proportion of each substrate type varied among individual quadrats, particularly at South Cove where several quadrats contained substantial proportions of cobble (up to 37.8% in Quadrat 13 or sand (up to 38.1% in Quadrat 15). In contrast, Lighthouse Beach and Sunset Bay quadrats were more uniformly rock-dominated (Figure 5). Analysis of percent cover including biological substrate points revealed that rock comprised an average of 30.4± 2.2% of the total UPC points, with cobble covering 5.1±1.3% and sand covering 1.0± 0.6% (Figure 6).

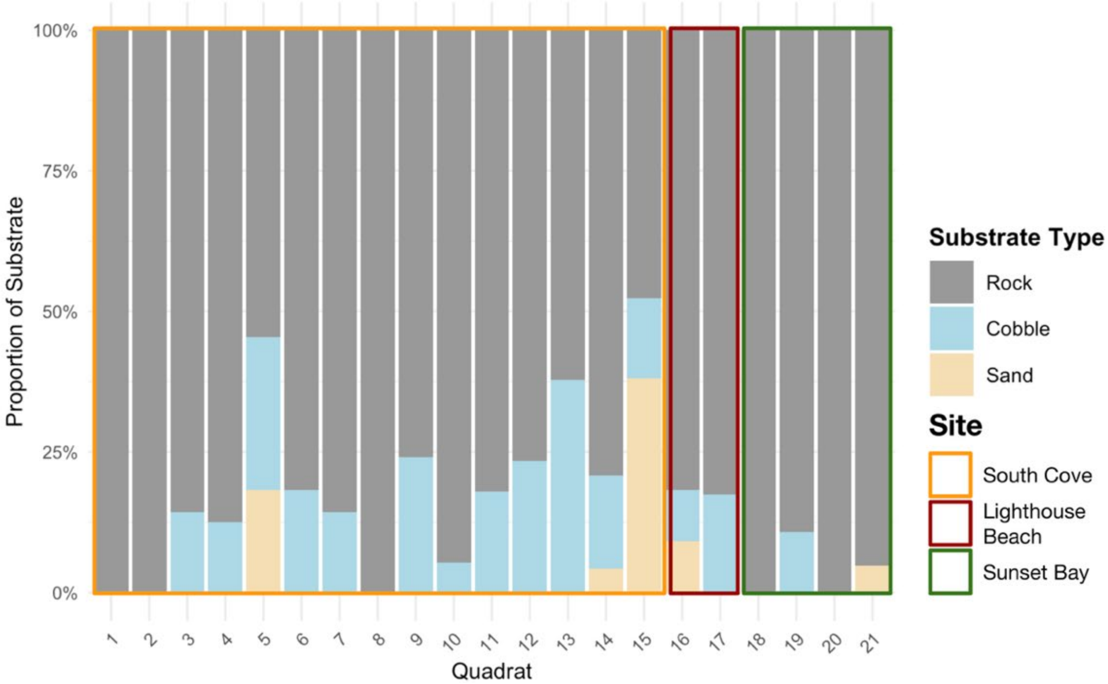

Figure 5. Substrate composition of individual quadrats containing *C. stelleri*, grouped by sampling site.

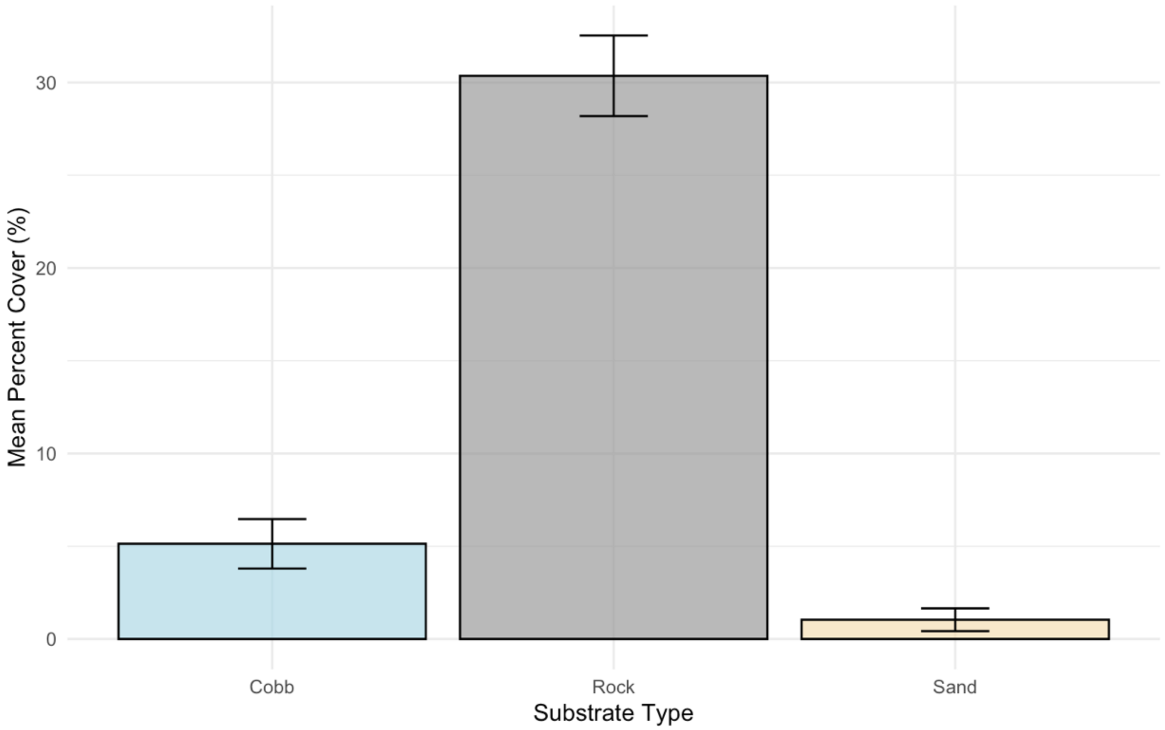

Figure 6. Mean percent cover of each substrate type. Bars indicate SE.

Structural Features

C. stelleri quadrats averaged 1.46 ± 0.08 surface rugosity, quantified using a rugosity index, indicating that habitat surfaces were 46% more complex than flat substrate on average. Most quadrats (76.2%) contained rock crevices, while overhangs and shade were present in 43% and 48% of quadrats respectively. The highest proportion of quadrats contained only crevices, with the next highest containing both crevices and shade (Figure 7).

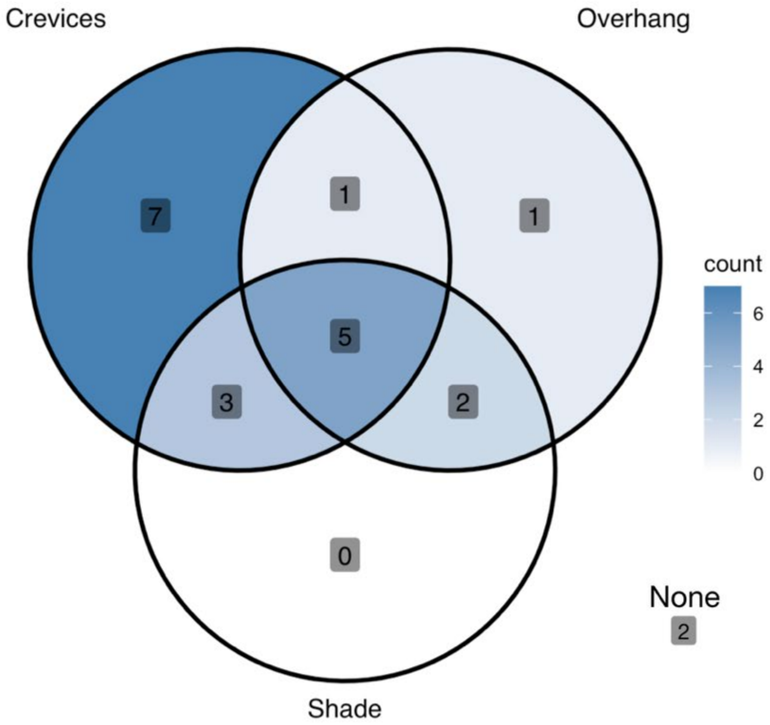

Figure 7. Counts of structural features of quadrats containing *C. stelleri* of n=21 quadrats.

Co-Occurring Taxa

Quadrats including *C. stelleri* also included an average of 8.8 ± 0.5 associated taxa per quadrat. The seventeen taxa occurring in >10% of quadrats were analyzed (Figure 8; Table 1). Red branching algae (redbran) was found in 100% of quadrats and was spatially dominant (23.8% average percent cover). Other common taxa included crustose coralline algae (crustca, present in 86% of quadrats) and *Mastocarpus* sp. (masto, present in 76% of quadrats), though these occupied less space (5.8% and 7.8% average cover respectively). Contrastingly, *Phyllospadix scouleri* (phsc) was present in only 33% of quadrats but relatively abundant when present with 17.2% cover on average.

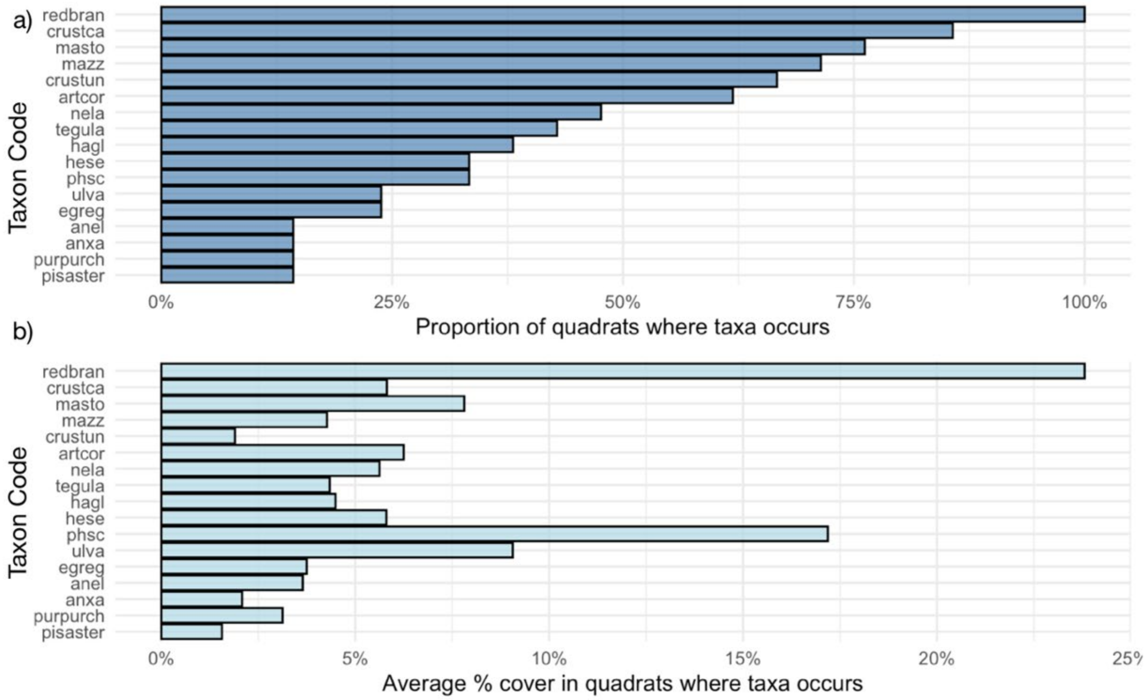

Figure 8. Abundance versus percent cover of taxa found in >10% of surveyed quadrats with C. *stelleri.* (a) Proportion of quadrats containing each taxon. (b) Average percent cover of taxa in occupied quadrats.

Table 1. UPC taxon codes and corresponding taxa for codes occurring in >10% of quadrats.

UPC Taxon Code	Taxa	Taxon ID type
Redbran	Red branching algae	Functional group
CrustCa	Calcified coralline algae	Functional group
Masto	*Mastocarpus* sp.	Genus complex
Mazz	*Mazzaella* sp.	Genus complex
CrustUn	Uncalcified crustose algae	Functional group
ArtCor	Articulated coralline algae	Functional group
Nela	*Neorhodomela larix*	Genus, species
Tegula	*Tegula funebralis*	Genus, species
Hagl	*Halosaccion glandiforme*	Genus, species
Hese	*Hedophyllum sessilis*	Genus, species
Phsc	*Phyllospadix scouleri*	Genus, species
Ulva	*Ulva* sp.	Genus complex
Egreg	*Egregia menzeisii*	Genus, species
Anel	*Anthopleura elegantissima*	Genus, species
Anxa	*Anthopleura xanthogrammica*	Genus, species
Purpurch	*Strongylocentrotus purpuratus*	Genus, species
Pisaster	*Pisaster ochraceus*	Genus, species

Lab Experiments

Feeding Rates

Chitons consumed less algae when handled than when unhandled (Figure 9). Feeding rates were significantly reduced with handling (β= -0.29, SE= 0.10, 95% CI= [-0.50, -0.08], t(21)=-2.91, p=0.008), resulting in a 35% mean reduction in feeding rates. Variance partitioning indicated that 52.8% of variance was explained by differences between individual chitons (σ =0.38), compared to residual variance (σ =0.34). The model explained 86% of the total variance, of which 4% was attributable to the fixed effect of handling.

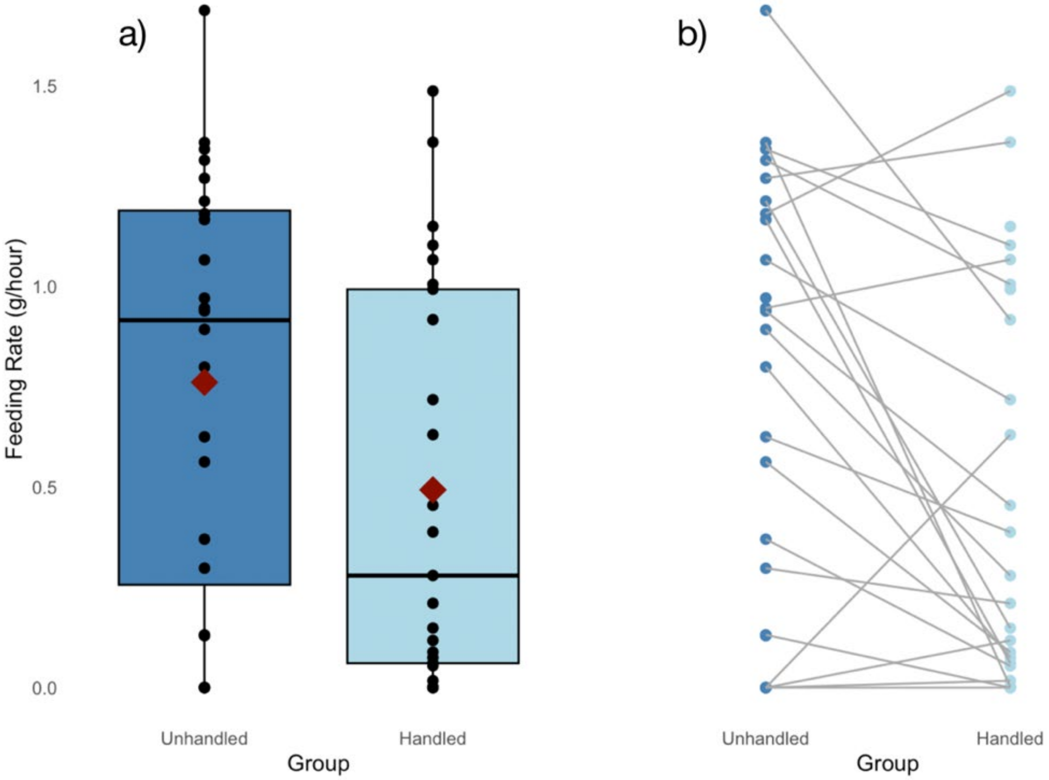

Figure 9. Effect of handling on *C. stelleri* feeding rates. (a) Distribution of feeding rates for handled vs. unhandled chitons. Red diamonds indicate means. (b) Feeding rates from repeated measures with connected points showing individual responses to both conditions.

Attachment Time

The length of handling also resulted in a significantly prolonged reattachment time (Figure 10), with individual chitons taking, on average, 25% longer to reattach after 10 minutes of handling compared to 5 minutes (β= 108.62, SE= 47.71, 95% CI= [10.36, 206.87], t(21)=2.28, p=0.032). The residual variance (σ =172.01) and random intercept variance associated with individual chiton identity (σ =237.62) indicated that 58% of variance was explained by differences between individual chitons. Fixed effects alone explained 3% of the variance, while the variance associated with both fixed and random effects explained 67%.

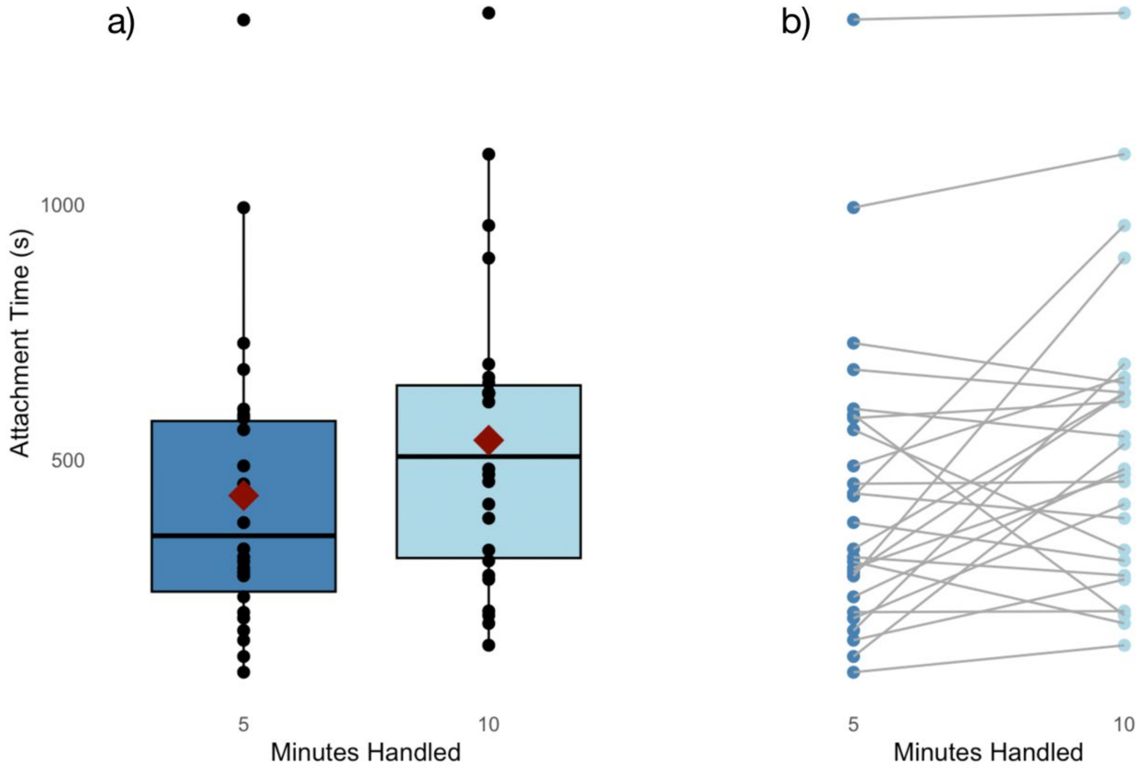

Figure 10. Effect of handling on *C. stelleri* attachment time. (a) Distribution of attachment times for handled vs. unhandled individuals. Red diamonds indicate means. (b) Attachment times from repeated measures with connected points showing individual responses to both conditions.

Righting Time

Righting time was extended by handling (Figure 11). Chitons took significantly longer to right themselves and reattach than when unhandled (β=153.62, SE= 50.9, 95% CI= [45.72, 261. 53], t(16)=3.02, p=0.008). This corresponded to a 9% mean increase in righting time. Seventy point four percent of the variance was attributable to among-individual variability (σ =355.49) in addition to residual variance (σ = 149.66). The model explained 59% of the total variance with 8% explainable by handling alone, demonstrating that most of the variance explained by the model was attributable to chiton identity.

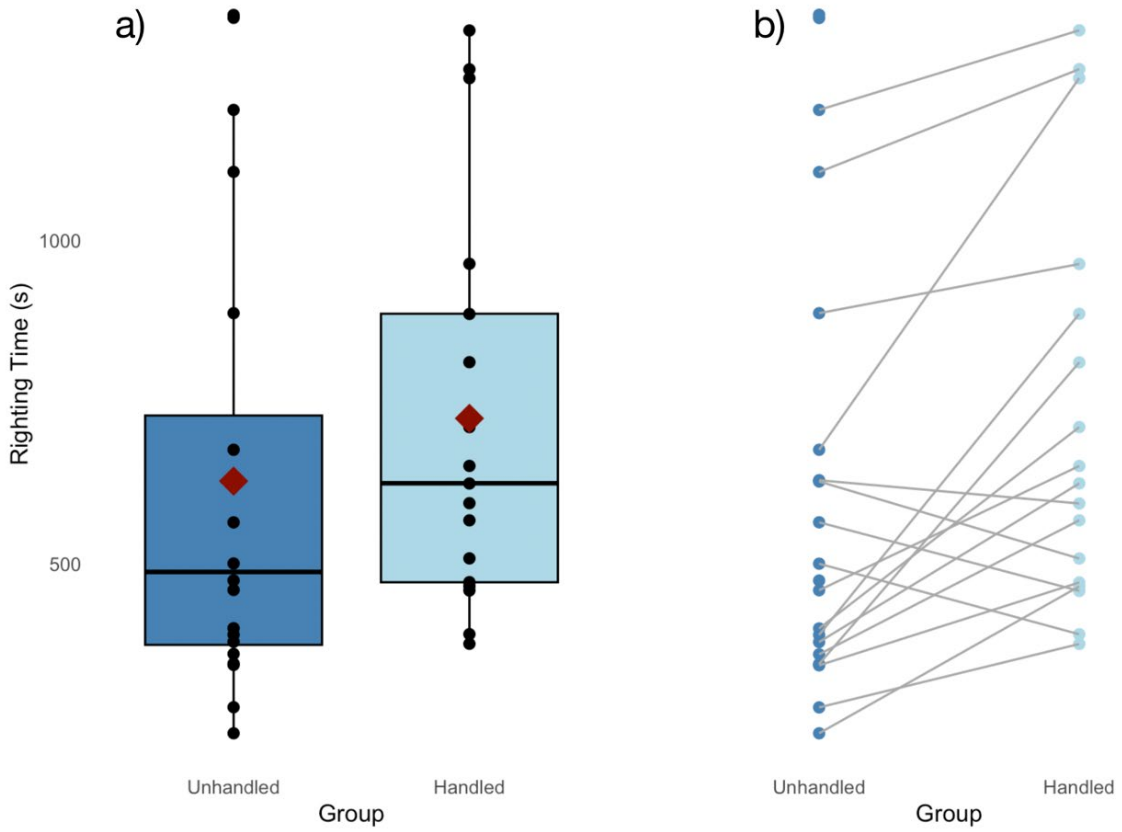

Figure 11. Effect of handling on *C. stelleri* righting time. (a) Distribution of righting times for handled vs. unhandled individuals. Red diamonds indicate means. (b) Righting times from repeated measures with connected points showing individual responses to both conditions.

Discussion

Laboratory experiments demonstrated measurable effects of handling on the behavior of *C. stelleri*, with handled individuals exhibiting approximately 35% lower feeding rates, 25% longer attachment times, and 9% longer righting times. These results provide evidence that direct human handling can alter the behavior and performance of the species, suggesting that even short-term interactions may temporarily disrupt normal functioning in gumboot chitons.

The substantial among-individual variation in the statistical model observed across all lab trials may reflect inherent differences among individuals. While the addition of chiton mass and/or site of collection did not strengthen the model and were therefore not included, these and other factors such as age or the degree of previous handling could also contribute to individual variation in behavioral responses, and their effects could potentially be demonstrable with a larger sample size. Despite this individual variability, the consistency of altered behavioral responses across trials and lab experiments demonstrates that disturbance of *C. stelleri* by handling does cause measurable impacts.

Field survey data corroborate earlier research demonstrating that *C. stelleri* primarily occupies structurally complex rocky habitats, as these areas likely offer increased protection from wave action and subsequent dislodgement and possibly allow shelter from thermal stress during low tide. Structural environmental complexity may also aid in righting, as previous studies have shown that an inability to right in chitons in lab settings may be attributed to a lack of physical structures to aid mobility (Sigwart et al., 2019). While handling increased righting time in the lab, actual intertidal surface complexity should also be considered when applying these findings in the future.

Survey data also showed that red branching algae were universally present in microhabitats occupied by *C. stelleri*. Crustose coralline algae and *Mastocarpus* sp. were also observed more frequently than *Mazzaella* sp., *C. stelleri's* preferred food source. Previous observations have demonstrated that although gumboot chitons display feeding preferences, these do not appear to exclusively determine their distribution, as less-preferred algae species are still eaten when encountered (Yates, 1989). The presence of *Mazzaella* sp. as a frequently co-occurring taxon is expected due to preference, but it is unclear from this experiment whether red branching algae, crustose coralline algae, and *Mastocarpus* sp. are simply widespread within the study area or whether they also represent preferred food sources for *C. stelleri*. The high frequency of red branching algae in *C. stelleri* microhabitats may also reflect their feeding preference for *Cryptopleura* sp. (Yates, 1989). Additionally, crustose coralline algae serves as a settlement cue for larval gumboot chitons, another factor in determining distribution (Lord, 2011). The relatively frequent presence and high cover of *Phyllospadix scouleri* should also be investigated as a co-occurring species associated with *C. stelleri.*

The behavioral effects of handling identified in this study also point to potential ecological consequences. Because *C. stelleri* are long-lived, large grazers with strong site fidelity and patchy distribution, the possibility of short-term disruptions could alter fine-scale patterns of algal abundance or community composition (Yates, 1989; Lord, 2011). Removal experiments have not yet been performed regarding this species, as they have for other chitons or intertidal invertebrates, and such studies would better explain how handling might lead to cascading trophic effects or possible ecological dynamics involving other herbivores, dynamics previously demonstrated with similar species (Dethier & Duggins, 1994). Removal studies would also help clarify the spatial scales at which the effect of handling *C. stelleri* could be ecologically relevant and provide a comparison to evaluate the ecological impact of handling in relation to other detrimental activities such as trampling (Addessi, 1994).

Rough coastal conditions, limited site access due to tides, and limited time constrained the sample size and replication, so the trends observed here should be verified with additional organisms and trials. Further, the experiments related to the effect of handling in this study were performed under controlled conditions, which do not account for the variability and stressors common in the intertidal. Factors such as thermoregulation, desiccation, and wave action likely interact with handling in complex ways. Logistical challenges surrounding temperature measurements prohibited an effective study of this specific element of handling, since infrared scanners introduced error, sometimes to the extent of ±2°C, and therefore did not allow for accurate measurement of the likely minute changes in temperature experienced by a chiton during handling. Other methods of measuring core temperature, such as immersion thermometers, required handling the chiton for operation, which did not allow for an effective measure of temperature for unhandled individuals.

Additionally, the tagging process and presence of the zip tie used for identification may also have altered the behavior or limited the movement of the gumboot chitons. However, as both the handled and control experimental data came from animals that were tagged, any tagging effects were applied to all animals. Future studies should also assess the consequences of tagging. Additionally, due to limitations in the tank space available to hold chitons during experimentation, tagging was required to identify animals during experiments, but future studies with sufficient aquaria could replicate the experiment without requiring tags. It should also be noted that all handling performed in this study exposed the chitons to air, so the potential compounding or related effects of handling, desiccation, and temperature cannot be separated. However, this type of handling mimics what occurs during natural interactions in the field, so it still provides a useful metric for analyzing behavioral changes.

To build upon the findings presented here, several questions should be addressed in future research. These include identifying the physiological mechanisms driving behavioral changes, determining the potential lasting effects of handling, and assessing its influence on outcomes such as survival, reproduction, site fidelity, and predation. Future studies should prioritize *in situ* experiments, potentially including mark-and-recapture studies, and test the effects of handling over varying timescales. Manipulative field experiments such as removal studies, exploration of physiological markers of stress, and formal assessments of handling under varying factors such as thermal stress or desiccation would also be valuable.

Future work should aim to determine the mechanisms responsible for the observed changes in behavior. Possible explanations could include muscular fatigue or interference with chemosensory perception, but further research would be required to validate the relevance and impact of these factors. Alternatively, behavioral changes after handling (especially those related to feeding) could represent adaptive shifts in energy allocation, with decreased grazing rates reflecting a shift from feeding to immediate survival processes such as maintaining adhesion. This would be consistent with the notion that chitons are less active in areas with a high potential for disturbance, such as wave-swept zones, because movement during grazing increases dislodgement or predation risk (Lord, 2011; Yates, 1989). Energy reallocation could also explain the prolonged attachment and righting times, since rolling into a ball and maintaining this defensive position in response to handling may be energetically costly (Sigwart et al., 2019). Studies addressing temperature specifically could follow previous studies regarding thermoregulation and thermal stress in intertidal invertebrates, using biomimetic models to measure body temperature changes during handling and specific tests for expressions of thermal stress such as heat-shock proteins (McIntire & Bordeau, 2020; Helmuth et al., 2001). Finally, the degree to which behavioral changes represent involuntary impairment as opposed to strategic behavioral adaptation also requires further study, as previous research suggests chitons may be capable of strategic behavioral responses (Sigwart et al., 2019; Sumner-Rooney & Sigwart, 2018).

Ultimately, evidence for behavioral effects due to short-term handling demonstrates that human handling can alter the behavior of *C. stelleri* in measurable and potentially ecologically relevant ways in a laboratory setting. While this study does not fully address all the factors involved in handling and the potential ecological implications, it lays the groundwork for future work that could link handling-related and ecological data. Understanding the impacts of handling is also useful when designing experiments or observing animals in the field to account for potentially altered behavior due to interaction. Demonstrating the impacts of short-term handling, even in a lab setting, emphasizes the importance of minimizing unnecessary disturbance and accounting for behavioral impacts that might usually be overlooked in human–animal interaction or experimentation.

Ethical Analysis

Introduction

Both science and ethics are methods of truth seeking. Science seeks to establish truth through objective inquiry and empirical data. Ethics explores the nature of truth and our responsibility towards it. The two fields rest on the same foundation but are often separated in modern contexts. The ethical analysis portion of this study incorporates the results of the biological data gathered through experimentation. I explore whether the biologically observable effects on *C. stelleri* constitute harm that can be morally justified considering the educational or research benefits derived from handling the organisms. I also offer ways scientific practices should change considering this biological and ethical evidence.

I also consider broader contextual factors, including the cultural significance of Indigenous knowledge systems and overall ecosystem health through the lens of human interaction and disturbance. I acknowledge that Many Indigenous groups in the Pacific Northwest, including the Tlingit, Tsimshian at Lax-Kw'alaams, Kwakiutl (Kwakwaka'wakw), Manhousat (Nuu-chah-nulth), Nootka (Nuu-chah-nulth), Coast Salish, and Alutiiq, use gumboot chitons as a traditional food source (Cline, 2024; Croes, 2015; Harbo, 1997; Miraglia, 2002; Moss, 1993). These groups are primarily located in southern Alaska, Vancouver, British Columbia, and the US-Canada border region near Washington.

In my analysis, I aim to decenter traditional Western conceptions of science and instead emphasize the interconnectedness of all life, where no individual entity exists independently of its surroundings. I recognize marginalized frameworks that promote experiential knowledge and respectful human integration into ecosystems (TallBear, 2017). This perspective contrasts with the often reductionist scientific methodologies that seek to understand isolated parts of a whole (Deloria, 2016; Atleo, 2004).

Biological Data

The biological data documented in this study provides a useful foundation for ethical exploration. I found that handled chitons experience measurable physiological and behavioral detriments: on average, they feed 35% more slowly, take 25% longer to reattach, and 9% longer to right. These findings indicate significant harms following handling that may directly impact both organism survivorship and the integrity of experimental data. This is an important contribution to the scientific literature, as it expands what we know about this species and provides a concrete basis for ethical reflection. Knowing these numbers gives us a concrete way to think about ethically experimenting and interacting with chitons. For example, these results provide answers to questions such as: How might picking up *C.stelleri* change its feeding rate, and how might that influence scientific data and interpretation? Is the tide coming in, and therefore will a handled chiton that takes longer to reattach be at higher risk for dislodgement? How will the stress of experimentation contribute to mortality and a reduction in biological function, leading to the decreased well-being of the animal and possible ecological consequences?

Yet while such results are both scientifically and ethically valuable, they are not the sole foundation of ethical treatment. Even without these significant findings, questions would remain, because ethics and science do not operate independently. I argue that the presence of measurable detriments does not justify a prohibition on handling. Instead, these biological results highlight the need for a framework that acknowledges the inevitability of human interaction with the environment and emphasizes minimal harm in engagement, while still enabling the production of biological knowledge.

Ethical Frameworks

Two useful ethical terms to consider while incorporating philosophy into scientific human-animal interactions are kincentricity and pragmatism. Kincentricity, a term coined by Indigenous ecologist Dennis Martinez in 1995, describes the Indigenous conception of ecological resilience as a “law of circular interaction,” similar to Western notions of sustainability (Martinez & Hall, 2008, p. 2). Kincentricity describes the ways in which Indigenous ecological knowledge does not adhere to strict definitions of good and bad, such as complete environmental harmony or unrestricted extractivism, but instead follow “the middle way, where we have a relationship not only with our immediate biological family, our extended family, our tribe, our clan, our community, but also with plants and animals out in the natural world...” (Martinez & Hall, 2008, p. 3). This kinship leads to resilience and adaptability, which in turn contributes to a “model of interdependence of all parts in nature, the flux of parts and whole” (Martinez & Hall, 2008, p. 2).

Dr. Enrique Salmón further expands on kincentricity, outlining the Indigenous belief that “humans are at an equal standing with the rest of the natural world; they are kindred relations...that the complex interactions that result from this relationship enhance and preserve the ecosystem” (Salmón, 2000, p. 1331). As Salmón states, the recognition of and immersion in these complex interactions reveals a reciprocal and non-hierarchical relationship between the environment, its constituents, and humans.

Kincentricity offers an effective framework for contextualizing and evaluating this relationship. By emphasizing humans’ roles within natural communities, kincentricity acknowledges the inevitability of these human-animal interactions by recognizing that all living beings are deeply interconnected through kinship. In doing so, it provides a method for engaging in ethical interaction, invoking a spectrum of better and worse interactions as opposed to starkly defined prohibitions or requirements.

Pragmatism is “the attitude of looking away from first things, principles, 'categories,' supposed necessities; and of looking towards last things, consequences, facts... that ideas (which themselves are but parts of our experience) become true just in so far as they help us to get into satisfactory relation with other parts of our experience” (James, 1907, p. 23). This emphasis on consequences as opposed to moral principles, on truth being satisfactory, adds to kincentricity by translating the complexity inherent in interactions between kin into contextual and iterative frameworks based on outcome as opposed to moral responsibility. Pragmatism also speaks to this non-hierarchical understanding of the natural world, stating that “...the claim to be ‘higher’ often blocks us from the wider recesses of experience, namely, from those affective sensibilities available only horizontally” (McDermott, 2004, p. x).

Drawing on kincentricity and pragmatism, I introduce a new term as a guiding principle for interactions with study organisms: interactive kincentricity. This term allows the "law of circular interaction" to become a framework for scientific practice with kinship as the starting assumption and pragmatist deliberation as the method. This framework recognizes humans as a "horizontal" and integrated part of the environment, highlighting the cyclical process of engaging ethically to understand study organisms, and simultaneously using that understanding to inform future interactions. By developing interactive kincentricity, I seek to explore the moral dimensions of science, because, as Indigenous philosopher and environmental justice scholar Kyle Whyte (2018) asserts, "the environmental dimensions of resilience are just as much issues of genuine moral responsibility—trust, consent, reciprocity, and more—as they are issues of biology and ecology" (p. 140).

I find pragmatism valuable in combination with kincentricity because it similarly seeks to follow "the middle way" and "introduces a further important component: being grounded in an approach that is pluralistic, fallibilistic, and flexible...in this way, pragmatism challenges received experience and inherited wisdom and impels people to be critical of their habits" (McKenna and Light, 2008, p. 9). While kincentricity also addresses practical issues with its assertion that humans and the environment intertwine in a tangible web of interaction, pragmatism explicitly aims to resolve complexity through what author Ben Minteer (2004) calls "a series of *practical* conflicts requiring the evaluation of competing goods and deliberation over alternative proposal and claims in specific cases requiring intelligent judgement" (p.104).

Both science and kinship are shaped by moral obligations, either to conservation, the production of knowledge, or to the life and well-being of nonhumans. These obligations can come into conflict with widely accepted scientific practices, as the pursuit of knowledge in Western science often necessitates some degree of harm. Pragmatism helps resolve these "competing goods," as it "[introduces] the prospect of weighing numerous and often competing goods in practical deliberations over right actions and judgments" and makes the conflicting moral obligations between animal well-being and scientific necessity actionable (Minteer, 2004, p. 107). Considering interactive kincentricity positions the scientific process of trial, error, and gradual improvement to be a central tenet of ethical interaction through fallibilism and allows for the creation of an ethical framework when relationships with nonhuman kin aren't necessarily harmonious.

As Indigenous philosopher Brian Burkhart says while describing *elohi,* the *Jalagi* (Cherokee) word for the intertwining of land, humans, and non-humans, "human beings come into existence with unresolvable tension and conflict with animals...But in the context of *elohi*, life-continuing or well-being is an intertwining of life and death, of the taking of life for life-continuing and the giving of life for life-continuing" (Burkhart, 2019, p. 19). Interactive kincentricity reflects this perspective, acknowledging that ethical interaction should not seek to eliminate conflict between humans and animals, but instead engage in reciprocal action and thoughtfully navigate tension. Interactive kincentricity, as a critical and contextual approach to human–animal interaction, bridges Indigenous and Western philosophical thought. It draws on concepts such as *elohi* and kinship, emphasizing the relationality and tension associated with animal interaction, and provides a way to examine these concepts in contexts informed by Western science and philosophy.

Embracing tension by utilizing interactive kincentricity teaches us to be better kin and better scientists. Often, science seems to reject closeness with study organisms in the name of objectivity, but human emotion is inextricable from how we interact with our study subjects. Rather than undermining objectivity, emotion can, under interactive kincentricity, serve as a guide to more ethical engagement. I argue that interactive kincentricity, by utilizing pragmatism, bridges the seemingly unavoidable gap between irrationality and objectivity, recognizing that "emotional connection and moral concern for others can be hidden through proximity. This is impartiality in the sense of fairness and a critical reflection on one's biases" (Kristensen, 2025, p. 47). In this way, impartiality does not involve complete separation from one's study organisms, and irrationality does not inherently lead to flawed scientific findings. In fact, "the thorny difficulties and conflicts of human experience [require] an experimental method of inquiry similar to that employed in the natural and technical sciences" (Minteer, 2004, p. 106). Accounting for emotion in science reflects the scientific process, as it builds on previous knowledge to determine both where emotions might cloud judgments (and therefore scientific conclusions) and where emotions might better foster animal wellbeing. Therefore, interactive kincentricity allows kinship to lead to valid scientific findings by combining the emotion associated with kinship with the pragmatic, iterative nature of science.

This iterative process takes time. While science rests on revision, I find time to be the driving logistical factor in scientific experimental design and execution--something science views as a limiting resource, especially when it's spent waiting, starting over, or moving backwards. During my study, I found myself thinking that I didn't have time to try another course of action–I had to work with urgency so I could meet a deadline or get to my sites before the tide came in–even if there were ways I could improve my ethical practices before embarking on the experiment. I recognize this lack of time as both a systemic issue in the structure of science, an interpersonal element of the culture of the field, and a general sense of urgency in the face of climate change and political resistance to scientific findings. I also acknowledge that time and the resources required to take one's time are a luxury, and that grants and scholarships and opportunities rest on completing experiments quickly.

However, I argue that interactive kincentricity requires time spent on non-production, on experiential learning and starting over. As Whyte states, "this way of thinking about science privileges empirical inquiry that is designed to achieve goals beyond the production of information. Science must be part of moral relationships, increasing human accountability to nonhumans and the environment" (Whyte, 2018, p. 141). Time is a resource (one of many) we must gift our study organisms, yielding kinship and reciprocity, and they will give us empirical data, knowledge, and fulfillment in return. This idea follows Whyte's description of Robin Kimmerer's call for humans to recognize "complex mutual responsibility…to be conscientious gift givers and gracious gift receivers" (Whyte, 2018, p. 140). Through time, we know our organisms better, and knowledge combined with a sense of kinship yields not only more ethical but more scientifically rigorous experimentation.

Maneuvering through complex scientific and ethical issues using interactive kincentricity requires "...[treating] moral relationships as complex systems working to promote adaptive capacity, not stagnancy" (Whyte, 2018, p. 140). For me, avoiding stagnancy meant recognizing that even when I couldn't achieve the best possible outcome for my experiment or my study organisms, the effort to do something better was still adaptive progress. "Consequences extend beyond the immediately perceivable end and are wrapped up in the entire process of deliberation and action. Further, consequences are not stagnant ends, as they create future possibilities, problems, and ends that are not yet in view" (Kristensen, 2025, p. 51). When ethical problems are approached only as fixed ends, "a binary between emotion and reason is maintained, which also fails to account for the emergence of numerous other consequences and future ends" (Kristensen, 2025, p. 53). Avoiding stagnancy in practice therefore involves adapting methodology based on both data and experience, while still moving forward with the best information available rather than waiting for perfect conditions. Time itself is both a resource and a gift, and ethical experimentation requires using it wisely, by making thoughtful decisions about interactions with study organisms while also prioritizing forward motion to continually learn through the process of experimentation.

Ethics in Practice

Throughout my research I learned to engage in ethical scientific interactions with gumboot chitons, but only after systematically disturbing them. This human element of science—the learning through experience, the self-reflection and contradiction—forms the body of this project. Without it, both the biological and philosophical analyses I present lack context and complexity. I fully recognize the importance of bias minimization in science, but the ethical treatment of nonhuman animals by humans requires introspection and examination of human emotion. I conducted, and will continue to conduct, my experiments with scientific rigor, but I claim that humans cannot be entirely separate or neutral observers--an acknowledgement that does not detract from scientific findings but can instead add depth and relevancy to the conclusions drawn from scientific animal interactions. Chitons taught me, through interaction, that the best and most ethical interactions with animals require hands-on, experiential relationships. Contradiction, complexity, and learning from experience are central tenets of any relationship, even scientific relationships with gumboot chitons.

To illustrate how interactive kincentricity shaped my own research, I turn to my lab experiments, since "rather than just providing principles to guide practice, [pragmatism] focuses on developing a critical approach to life in which all people can engage" (McKenna and Light, 2004, p. 9). Challenging my own scientific procedures and the constructs within the field that inform them has been an essential part of developing interactive kincentricity as a critical approach, one I will continue to engage with in my future work.

I performed many of my experiments in the laboratory, as I was conducting behavioral trials and manipulating chitons while controlling for environmental conditions. I attempted to make the lab environment as conducive to survival as possible by utilizing oxygen bubblers, checking on the animals frequently, and making sure to return them to the intertidal quickly. However, in the future, I would instead aim to spend as much time in the field as possible, utilizing immersive observation and eliminating the need for dislodging, transporting, and keeping the chitons. An emphasis on immersive observation reflects many Indigenous knowledge systems often excluded from Western science (Deloria, 2016; Atleo, 2004). Additionally, prioritizing in situ observation would not only reduce the stress associated with removal from a site but would better contextualize the data in site-specific ecology–especially for animals such as *C. stelleri* with strong site fidelity.

Similarly, I did my best to return the chitons to where I found them–at the site where I obtained them, at similar tide heights, and in microhabitats conducive to their survival (which I better understood through ecological survey during the course of my study). However, this wasn't possible for every organism, so I returned some to alternative sites. Future protocols should formalize returning animals to their origin sites and potentially include monitoring after returning to assess survivorship.

I also attempted to minimize pain and the possibility of infection or parasitism during the tagging process by using sterilized needles and completing the procedure as quickly as possible. In the future, though, I hope to instead try to find a less invasive method of identification, potentially by finding a nontoxic and removable wax or paint that to apply to the chitons' mantles, or to bypass the tagging procedure altogether.

In each of these examples, I recognize the elements of experiments I performed well and how I could improve, as opposed to starkly delineating my actions as good or bad. I used and will continue to use, especially as I learn more through ethical interaction, interactive kincentricity to maneuver through difficult scientific decisions. These actions illustrate interactive kincentricity because I had to utilize an iterative framework, learning how to better recognize the kinship in my study organisms *through* experimentation and then adjust my practices using pragmatist and practical observations. Following Kimmerer, I now better recognize that kinship necessitates inconvenience and extra effort taken to return the gifts of time and knowledge given to me by the organisms.

Frequently, however, those gifts go beyond knowledge. One particularly poignant experience occurred when one of my study organisms died after escaping into the lab during experimentation. This experience taught me that to be gracious gift receivers, we owe our study organisms consideration of their individual lived experiences. As Kristensen notes, "within both approaches to development and toward animal welfare, an emphasis on quantifying moral patients as units of utility de-individualizes their lived experiences" (Kristensen, 2025, p. 49). When the chiton in my care died, I wished I had more fully considered its individual lived experience before its death, but in its aftermath I did my best to honor its life by returning it to the ocean and allowing myself to embrace the emotions associated with the loss of an animal I had come to know and admire—feelings that, as I have established, do not undermine but instead enrich my scientific practice. I could have chosen to view this death in purely utilitarian terms, saying that only one out of twenty-seven collected chitons died, and that animal provided data that arguably justified the loss given the inherent risks of handling and keeping live animals. Interactive kincentricity provides a way to reconcile the grief and recognition of the chiton's lived experience with the empirical value its life and death contributed.

The combination of kincentricity and pragmatism prevents this experience from becoming judgement-clouding sentimentality or traditionally Western scientific reductionism. By assuming kinship, I acknowledged the chiton's individual lived experience and grieved its loss rather than dismissing it as merely one specimen among many. By utilizing pragmatism, I considered what this death meant practically for my experiments—what did I need to change to prevent future escapes? How might my emotions inform my scientific conclusions? Pragmatism allowed me to not only focus on these "fixed ends", but to transform them into a method for the "satisfactory relation" William James noted in his reflections on the philosophical field. In combination, interactive kincentricity provided an opportunity to iteratively reflect on both my kin relationships and scientific interactions with the chitons as a combined framework.

A Scientist's Guide to Interactive Kincentricity

Interactive kincentricity rests on two principles: 1) kinship as the starting assumption, and 2) pragmatism as the method. To assume kinship is to recognize every organism as a relative with its own lived experience. To act pragmatically is to engage with that kinship through deliberation, iteration, and careful attention to consequences. Together, these principles shape scientific endeavors into ongoing ethical relationships. What follows is a guide to incorporating these principles into engagement with animals. My aim is not to be prescriptive, but instead to attempt to apply ethical commitments to everyday scientific practice. In creating these guidelines, I follow previous endeavors that meaningfully apply Indigenous-led frameworks by articulating and formalizing values such as respect, responsibility, balance, communication, and reciprocity within scientific contexts (Lee et al., 2021). I'm similarly inspired by Max Liboiron (2021), researcher and anti-colonialist writer, who asks "…how do I get to a place where these relations are properly scientific, rather than questions that fall out of science, the same way ethics sections are tacked on at the end of a science textbook?" (p. 20). I hope these considerations become a method for creating "properly scientific" methods of engagement instead by creating a critical framework for interaction with animals that can be applied in multiple settings. As they are intended to help individuals engage in critical habits to evaluate their actions, these guidelines can also be applied outside of purely scientific settings, such as intertidal human-animal interactions.

1. Avoid hierarchies of cognition.

Do not assign moral worth based on how closely an organism's cognition resembles yours and assume more cognition rather than less. It is reasonable and necessary to have different frameworks for different animals based on their unique characteristics, but assessments of moral worth based on cognition shouldn't rest on a hierarchy of intelligence with human cognition at the top.

2. Recognize individual lived experiences.

Move beyond category labels such as vertebrate/invertebrate or taxa-related groups and instead attend to the individual lived experiences of the animals in your care. Regulations such as IACUC procedures protect vertebrates, but not invertebrates, and incorporating ethical frameworks such as interactive kincentricity encourages those who interact with animals to call that distinction into question.

3. Go beyond the minimum.

Kinship involves observing and moving beyond procedure. Act with care derived from personal observation instead of procedural obligation.

4. Learn through iteration.

Reducing stress for study organisms is not only an ethical act but also strengthens the quality of scientific conclusions. Science *and* learning to engage in ethical interaction are both iterative processes that take time, effort, and revision.

5. Be systematic, not detached.

Get to know your animals systematically and scientifically but not impersonally, as the animals you care about enough to study in the first place can be active teachers through interaction.

6. Choose inconvenience when necessary.

Ethical treatment requires sacrifices, including but not limited to: ending an experiment early, starting over with more informed methods, pursuing a labor intensive or logistically difficult methodology to reduce harm, slowly navigating through the intertidal with care, or dedicating time to specific, mindful, and intentional interactions that facilitate critical analysis of one's behavior as opposed to routine actions that reflect unexamined habits.

7. Treat animals as gifts, not utilities.

If their presence and the knowledge gained from organisms is a gift, ask yourself how you can return it and offer reciprocity, improved conditions, or better care in future work.

8. Trust discomfort.

Do not explain away an uncomfortable feeling about an interaction. Take time to reflect and adjust, even if it's inconvenient or unconventional. Emotion may feel at odds with rationality, but attending to ethics in science requires emotion and does not necessarily directly oppose impartiality.

9. Use time wisely.

Time is a scarce resource, so allocate it intentionally. Interactive kincentricity means slowing down when possible to make the best choices while still moving forward to keep learning and inform next steps. Take as much time as is reasonable to design your experiments and interactions and build in time to revise.

10. Communicate.

Think and *talk* about why you like the animals you engage with, what you've noticed about them, and what you've learned from spending time with them, not just your scientific findings (although these are also important). Not only does talking with others about your animals in this way likely solidify your obligation to them, but it also encourages other scientists to think about what ethics may look like in their pursuits.

Ultimately, through interactive kincentricity, I argue that scientists (and, more broadly, humans) cannot, and should not, avoid interaction with the animals we encounter. Avoiding or denying the inevitability of engagement with animals reveals a misunderstanding of humans' inextricability from the natural world. Therefore, ethical interaction should involve careful engagement, involving both scientific precision and the attentiveness we would offer to family. To treat study organisms as kin is to recognize that their lives are inseparable from our own work, and careful treatment deepens both ethical reflection and scientific insight. More developed kinship leads to more complete knowledge, and that, after all, motivates the scientific process.

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