

Shaw K, Smith D. 2026. Establishing a Long-term Study on the Population Dynamics of *Ptilosarcus gurneyi* (Orange Sea Pen) and Observations of its Interspecific Interactions. Northwest Science 99(2): *in press*.

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**Establishing a long-term study on the population dynamics of  
*Ptilosarcus gurneyi* (orange sea pen) and observations of its  
interspecific interactions**

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## Abstract

*Ptilosarcus gurneyi* (orange sea pen) is an ecosystem engineer which acts as structural habitat in sandy, subtidal ecosystems and has been largely overlooked in the Salish Sea for over fifty years. *P. gurneyi* is a colonial anthozoan from the family Pennatulacea that makes up large populations called “beds” along the northeast Pacific coast. Little is known about *P. gurneyi*’s current population dynamics, the makeup of its communities in the Salish Sea, or non-trophic interactions with other epifaunal organisms. The aim of this research was threefold: (1) to establish a long-term study on the site densities of a *P. gurneyi* bed in Burrow’s Bay, WA, (2) to approximate abundance of other epifaunal species in the bed, and (3) to observe interspecific interactions. To establish a long-term study site, four 100 square meter quadrants were set up as permanent plots which were surveyed by scientific divers. Site densities were calculated and compared to those of random transects in the bed to test if the permanent plot was representative of the average *P. gurneyi* density in Burrow’s Bay. Interactions and community makeup observations were taken using submerged cameras and direct field observations. A T-test determined that site densities from the plots and the random transects were significantly different from one another, however due to small sample size, it is recommended that this study be repeated to confirm significance. *P. gurneyi* was observed to be commensal and possibly mutualistic with multiple species. There is evidence to suggest that it may act as protection from high currents or predation. Future research could investigate how *P. gurneyi* population dynamics change at this site.

## Key Points:

- *Ptilosarcus gurneyi* is an important species in the Salish Sea which has been largely neglected in research for over fifty years.
- Population surveys were taken via scientific divers in a permanent plot to begin a long-term data set on population size.
- Observations of *P. gurneyi* showed evidence of symbiotic relationships with other epifaunal organisms like fish and crustaceans.

**Keywords:** commensalism, marine invertebrate ecology, Salish Sea ecology

## Introduction

As coastal oceans worldwide face unprecedented anthropogenic threats, it is important to have reference levels of the populations of foundation species to aid in their ecosystem-based management (Samhuri et al. 2011). Some of these organisms have been largely overlooked, which may be detrimental to future research or potential conservation efforts. One such ecosystem builder in sandy subtidal environments is *Ptilosarcus gurneyi* (orange sea pen) which is a colonial anthozoan from the order Pennatulacea (sea pens).

*P. gurneyi* is a filter feeder with a primary polyp, the oozoid, which is composed of the basal peduncle that anchors the colony in the sediment and the rachis that supports the colony with a calcified axial rod (Figure 1). *P. gurneyi* and other Pennatulaceans have been found to have annual growth, as shown by rings in their axial rods, and slow maturation rates (Birkeland 1974, Neves et al. 2015, Wilson et al. 2002). *P. gurneyi* colonies have been found as old as fifteen years (Birkeland 1974). The secondary polyps bud off the rachis and serve various functions: siphonozooids bring in and expel water from the colony for expansion and contraction

and autozooids are responsible for feeding and reproduction (Figure 1). Beyond this expansion and contraction behavior, *P. gurneyi* is mostly sessile but have been observed to uproot from the sediments and drift (Birkeland 1974).

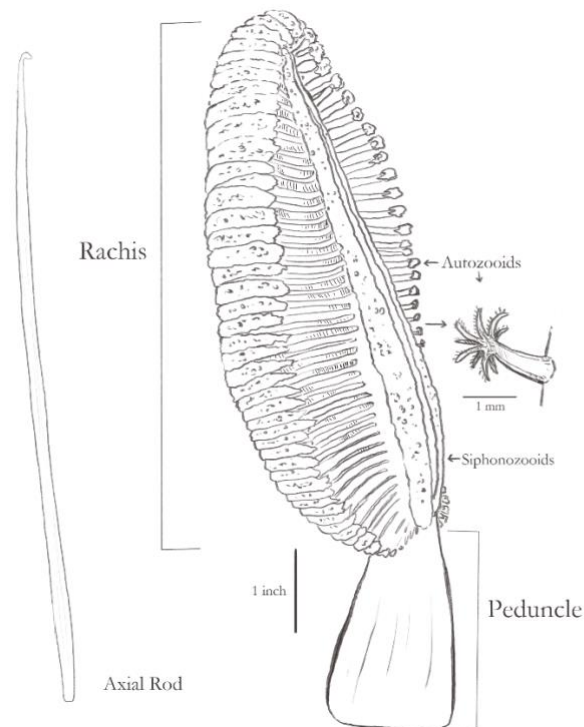


Figure 1. Illustration depicting a *Ptilosarcus gurneyi* colony with major features highlighted.

*P. gurneyi* is endemic to the west coast of the Americas from Southern Alaska to central Peru and occupies depth ranges from ten to four hundred meters, making them a shallow water Pennatulacean (Williams 2011). Throughout these depth and spatial regions, *P. gurneyi* colonies form populations called sea pen “fields” or “beds.” These beds provide structural habitat for other organisms and food for multiple predators, many of whom are specialized to *P. gurneyi* (Baillon et al. 2014, Birkeland 1974, De Clippele et al. 2015). These predators include nudibranchs such as *Armina californica* and *Tritonia festiva* as well as some sea stars like

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*Dermasterias imbricata* (Birkeland 1974). *P. gurneyi* has been shown to provide shelter from currents and predators for various species, particularly small invertebrates (Baillon et al. 2014, Johnstone 1969).

The Salish Sea, a large and biologically rich water body off the west coast of Washington State, is one home of *P. gurneyi*. The Salish Sea includes the Strait of Juan de Fuca, Puget Sound, and Strait of Georgia. The rivers that feed into it and organisms that live there make it incredibly important environmentally, culturally, and commercially. *P. gurneyi* has been found in the Salish Sea from the South Puget Sound near Olympia northward (Birkeland 1974) but remains largely overlooked in recent research. The last studies cataloguing their populations and community interactions within the Salish Sea were conducted in the 1970s (e.g. Birkeland 1974). Current research similar to these studies focus on single population counts for deep sea Pennatulaceans within the Atlantic Ocean (e.g. Baillon et al. 2014, Hughes 1998, De Clippele et al. 2015, Langton et al. 1990).

Since the population densities of these organisms and their interactions with their communities in the Salish Sea have not been thoroughly established, there is no way to identify how these community dynamics may change over time, either naturally or because of anthropogenic causes such as ocean acidification or pollution. Knowing these sorts of changes is especially important for these organisms since they form structural habitats and have long growth cycles which may significantly delay recovery in the event of a catastrophic event, whether natural or anthropogenic (Neves et al. 2015).

The purpose of this research is therefore to (1) establish a long-term population dataset for a bed of *P. gurneyi* colonies within Burrow's Bay (central Salish Sea, north of Puget Sound),

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(2) characterize community interactions, and (3) estimate epifaunal species abundance of this bed. This study will include an initial determination of site densities which can be expanded upon, allowing future research to monitor population dynamics of this essential ecosystem builder based on these initial data. Descriptions of community interactions will further demonstrate the importance of *P. gurneyi* to other epifaunal organisms within this environment.

## Methods

### Study Site

Burrow's Bay, Washington, is a 6.5 nm by 1.5 nm inlet protected by Burrows and Allen Islands to the west and bordered by Alexander Beach, a small beachfront housing community, to the east. At the north end of Burrow's Bay is Skyline Marina, a small commercial and recreational port within Flounder Bay protected by a natural spit with 710 slips, which are a combination of private docks and 465 condominium moorages. Small passenger ferries taking foot passengers to islands not serviced by the WA State ferry system frequently arrive and depart from the marina daily year-round. During crab fishing seasons, commercial and recreational vessels berthed in Skyline Marina use Burrow's Bay heavily for crab trapping. Shannon Point Marine Center has two research vessels berthed in Skyline Marina, making access to study sites in Burrow's Bay possible nearly year-round and with only a small investment in time and money. Scientific divers from Shannon Point Marine Center and Rosario Beach Marine Laboratory have been diving in Burrow's Bay for decades and have reported the presence of *P. gurneyi* beds over that entire time span, although the geographical extent, population densities, and density variability have not been quantified in peer reviewed publication or in grey literature to our knowledge. A permanent plot comprised of four one-hundred square meter quadrants was

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established in Burrows' Bay at 48.467950, -122.659564 haphazardly within the sea pen bed where the entire plot would be inhabited by sea pens colonies (Figure 2). The site is characterized by high current velocity during ebb and flood stages. The fine substrate also makes the site relatively featureless besides the sea pen bed and large detached brown and green algae.

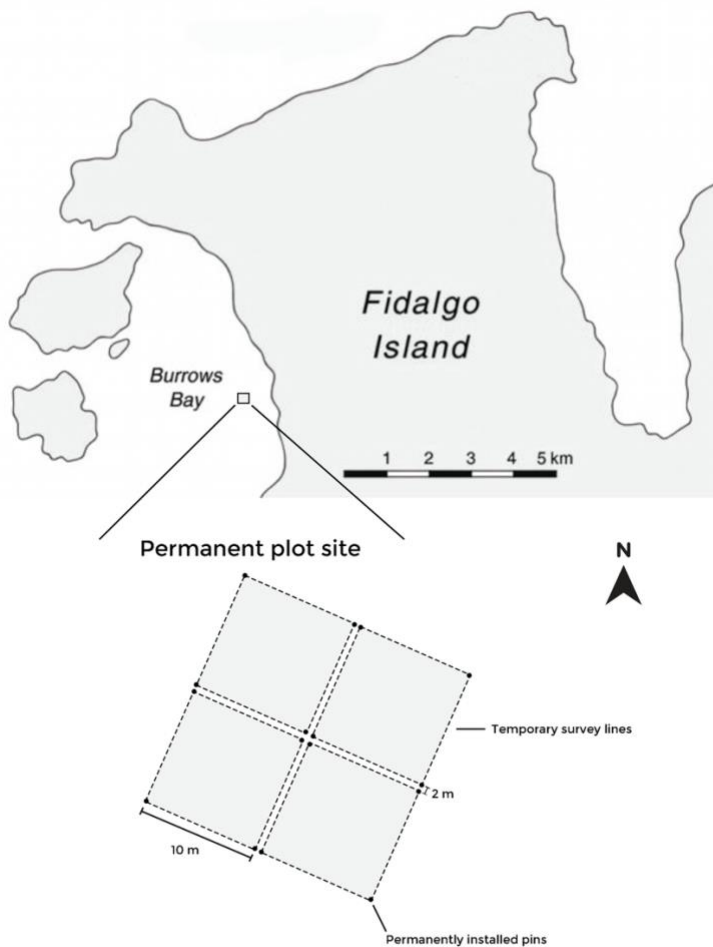


Figure 2. Location of study site in Burrows Bay, WA and permanent plot layout.

The quadrants sit approximately 7.9 m deep MLLW within a wide-spread population of *Ptilosarcus gurneyi* colonies. Sixteen rebar posts one meter long and two centimeters in diameter were pounded upright 80 cm into the sediment, leaving 20 cm exposed, forming the corners of

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each ten-by-ten m quadrant (Figure 2). Each corner was given a unique set of colored cable ties to aid in identifying spatial position of the plot. Each quadrant has a distance of two meters between them. At the start of each survey effort in July 2024, divers located the corners of the plot and deployed meter tapes wrapped around each post to form the outline of the four quadrants, which also formed the two meter wide lanes between the quadrants. Divers cleaned the tapes every few days to remove drift algal biofouling that could cause the lines to bend.

#### Site Density Determination

Multiple teams of scientific divers surveyed the plot visually by counting each colony within the quadrants on July 17, 18, and 24. Colonies were differentiated as adults or juveniles based on their coloration and height. For the purposes of this research, any colonies with light pigmentation and under twenty centimeters fully expanded were considered juveniles and anything above that to be adults. The height cut off was based on past research which found the smallest egg-bearing colony to be around twenty-four centimeters in live height (Birkeland 1974). When encountering colonies that were partially retracted into the sediment, where the colony could be seen but height could not be determined, the colony was assumed to be an adult. Divers did not disturb the sediment to locate colonies that were fully retracted. Survey times were always planned around the slack current so the divers would have the easiest time determining their position and conducting their counts, though often times the duration of dives resulted in the current speeds increasing. As currents increased, counts were made while pairs of divers oriented into the current and maintained the swath counts. One of the divers in each team would use their finger to trace a line drawn in the substrate to delineate where counts had already been made to avoid double counting any colonies.

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Count data were divided by the area of the quadrant to find the corresponding quadrant density:

$$\text{Quadrant density} = \frac{\text{Number of colonies per quadrant}}{\text{Total area of quadrant}}$$

Each quadrant survey represented a replicate count to calculate a total density of the entire permanent plot site:

$$\text{Total site density} = \frac{\Sigma(\text{Quadrant density estimates})}{N \text{ Quadrant density estimates}}$$

A total of five quadrant surveys were conducted over three days. The standard error and confidence interval of that site density average was computed in R (R Core Team 2023).

To test if the permanent plot was representative of the average *P. gurneyi* density in Burrow's Bay, six random twenty square meter transects were surveyed. These transects were made by haphazardly dropping anchor approximately fifty meters from the permanent plot at 48.468206, -122.660721 and within the *P. gurneyi* population. Meter lines were laid out toward three headings off the anchor line: 0°, 120°, and 240°. Two ten-meter transects were counted for each heading with five meters between them for a total of six 10-meter transects. All colonies falling within one meter of the lines on both sides were counted for twenty-square meters in total per transect. Random transect densities and a random transect site density were calculated using the same equations from the permanent plot site. Resulting densities were compared to the average site density of the permanent plot using a two-sample T-Test computed in R (R Core Team 2023).

#### Field Observations and Camera Deployment

Observations of interspecies interactions and community make-up were accomplished using direct observation and photography by three different divers during day and night scuba dives and with the use of deployed cameras. The cameras used were two GoPro Hero Ones encased in waterproof housings. The cameras were programmed using Cam-Do TL-002 Timer Controllers. The two GoPro Hero Ones were deployed using scuba twice over an approximately 24-hour period from July 16-17, 2024, and July 24-25, 2024. The resulting footage was a mixture of video lengths and intervals from five-minute videos every hour to two-second videos every fifteen seconds. Although the cameras were programmed to record for a 24-hour period each deployment, only footage captured during daylight hours were used as it was not possible to use lights with this GoPro setup. The cameras were deployed within the permanent plots where one was pointed toward an adult *P. gurneyi* colony and one faced a juvenile colony.

All observations were compiled and summarized to approximate species abundance and characterize community interactions.

## Results

### Site Densities

Mean total site densities from the permanent plot site and the random transect site were found to be significantly different from one another at a significance level of 0.05,  $t(9) = -6.82$ ,  $p < 0.001$ . Site density data calculated from counts of *Ptilosarcus gurneyi* colonies met normalcy and homoscedasticity requirements. The mean total colony density within the permanent plot site was found to be 0.838 colonies  $m^{-2}$  with a 95% CI [0.612, 1.064] whereas the mean total colony

density of the random transect site was 2.175 colonies m<sup>-2</sup> with a 95% CI [1.753, 2.597] (Figure 3).

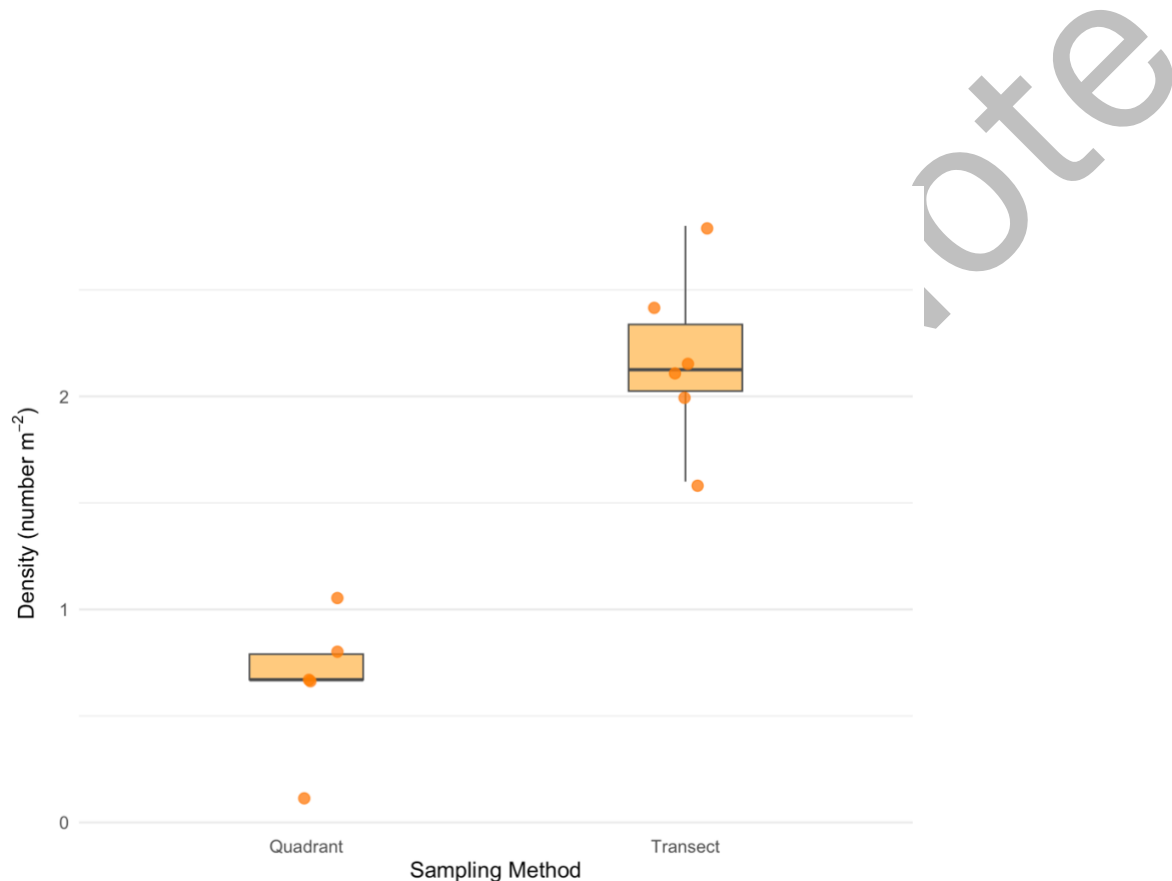


Figure 3. Mean total colony densities by sampling method.

#### Observations of Inter-species Interaction and Community Makeup

Observations from camera footage and field work revealed multiple interactions of various fish, crustaceans, and nudibranchs with *P. gurneyi* colonies. The total observed mobile epifauna in July 2024 included three fish species (*Lepidogobius lepidus*, *Lepidopsetta bilineata*, and *Squalus suckleyi*), at least three crustacean species (*Metacarcinus magister*, *Pandalus* sp.,

*Oregonia gracilis*, and an unidentified crab), and two nudibranch species (*Armina californica* and *Tritonia festiva*) in addition to *P. gurneyi*. The species of one crustacean could not be determined due to poor video quality. Observations are summarized in Table 1.

<b>Interaction</b>	<b>Species*</b>	<b>Observation Method</b>	<b>Observations (n)</b>
Sitting below colony	<i>Metacarcinus magister</i>	Scuba	2
Leeward of peduncle	<i>Lepidogobius lepidus</i>	Deployed Camera	12
Leeward of peduncle	<i>Lepidopsetta bilineata</i>	Deployed Camera	4
Atop of colony	<i>Oregonia gracilis</i>	Deployed Camera	1
Atop of colony	Unidentified crab	Scuba	1
N/A	<i>Squalus suckleyi</i>	Deployed Camera	1
Predation	<i>Armina californica</i>	Scuba	1
N/A	<i>Tritonia festiva</i>	Scuba	1
N/A	<i>Pandalus sp.</i>	Scuba	>40

Table 1. Brief descriptions of interactions with *P. gurneyi* for every observed epifaunal species, the method used to record the observations, and number of observations. N/A=present but not interacting with a colony. When species could not be identified, the closest taxonomic group was used.

From deployed camera footage, *L. lepidus* and *L. bilineata* were often seen sitting on the substrate in close proximity to the peduncles of the colonies (16 observations). During field work, the *P. gurneyi* colonies were observed turning their dorsal side and siphonozooids toward the current. With that information and the direction of algae drift observed in camera footage, it was determined that the fish typically sat leeward to the oncoming current behind the peduncles.

One observation was made of *S. suckleyi* from the camera footage; however, it did not interact with the population as it swam over it (Figure 2).



Figure 2. Photo from deployed camera of *S. suckleyi* swimming over *P. gurneyi* colony  
(07.26.2024)

During field observation, two *M. magister* individuals were seen sitting below two adult *P. gurneyi* colonies (Figure 3). These observations were made at night.



Figure 3. Photos of two *M. magister* individuals sitting underneath *P. gurneyi* colonies (Left: Toren Lawley 07.25.2024; Right: Ayden Jacobs 07.25.2024).

One observation of an unidentified crustacean from deployed camera footage showed it sitting on top of a colony windward to the current before it crawled to opposite side of the colony (see supplementary files). Another field observation showed a similar interaction with *O. gracilis* (Figure 4). Both of these observations were made at night.



Figure 4. Photo of *O. gracilis* sitting atop an adult *P. gurneyi* colony (Credit: Ayden Jacobs 07.25.24).

During an observation dive which took place at night, many *Pandalus* spp. individuals were observed sinking from the surface over the *P. gurneyi* population but they did not interact with the population. This was the only time this species was observed within the bed for the entirety of this research.

Of the two nudibranch species observed, *T. festiva* was only seen once and did not interact with the *P. gurneyi* colony it was next to (Figure 5). Multiple observations were made of *A. californica*, however only one observation also captured a predation event of a juvenile *P. gurneyi* colony (Figure 5). In every other observation of *A. californica*, the nudibranchs were seen above the sand within the population but not actively predated upon the colonies.



Figure 5. Left: Photo of *A. californica* preying upon a juvenile *P. gurneyi* colony (Credit: Derek Smith 07.25.2024); Right: Photo of *T. festiva* near a juvenile *P. gurneyi* colony (Credit: Ayden Jacobs 07.25.2024).

## Discussion

### Site Densities

Comparison of site densities from the permanent plot site and the random transect site revealed the permanent plot site had a significantly lower mean total site density than the random transect site. However, with the limited data collected from both sites due to time constraints from intense tidal exchange and number of divers, it is still unclear whether the plot is representative of the sea pen bed as a whole and we can only begin to assess the overall makeup of the sea pen bed in Burrows Bay. Since the permanent plot was established randomly within the sea pen bed simply based on the presence of the pens, this finding speaks to the variability in the distribution of these organisms.

Comparison of the permanent plot and random transects is further complicated because *Ptilosarcus gurneyi* colony groups appear to simultaneously expand and contract into the substrate randomly regardless of tidal stage, current, turbidity, light, season, or time of day except during predation events (Birkeland 1974). With a multitude of transect surveys at different locations, rather than one anchor point, this randomness could be accounted for. It is unknown whether the random transects were counted during a random time when more of the colonies happened to be “up” (expanded) than “down” (contracted) compared to the permanent plot quadrants or not.

Comparing these data to other such studies helps us begin to recognize long term patterns. The site densities of *P. gurneyi* within Burrow’s Bay are far lower than those from surveys conducted in Puget Sound fifty years ago. Population densities from this research ( $0.838 \pm 0.226$  colonies  $m^{-2}$ ) are two orders of magnitude less than those found by Birkeland in 1974 in the Puget Sound ( $22.7 \pm 7.9$  colonies  $m^{-2}$ ). A more recent study by Kyte (2001) showed that the large populations described by Birkeland (1969) are no longer present and remaining populations

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are relatively sparse and patchy. In another long-term study on near shore ecology from 2008-2014 by Rubin et al., there were not enough data to make any comparison to the current study (n=3). A technical report produced in November 2014 for Port Metro Vancouver for the potential expansion of the Roberts Terminal 2 in Vancouver provided similar insights to the present study, finding that sea pen beds are not comprised of single age classes and provide habitat for several other species, and that associated fauna (e.g. crustaceans, sea stars, anemones, and fish) are more likely to occur within areas of continuous to dense sea pens relative to areas where distribution is few to patchy or absent (Hemmera 2014). This confirms the need for continued monitoring of this species. More research is needed to address whether this difference is due to spatial factors, changes in time or resource availability, or simply the inherent properties of these populations.

Despite the current lack of data, the primary objective of this research was to initiate a long-term study, which was accomplished. Continued data collection at this site would allow future research to explore the population dynamics and behaviors like possible movement in these ecologically important organisms (C. Birkeland, personal communication, December 15, 2023).

#### Community Makeup

The observed mobile epifaunal species abundance in this population was low (n ~ 9). This is to be expected in featureless environments like the sandy subtidal where there is a lack of structure for large primary producers to grow. Past research also suggests that biodiversity may be similar for different pennatulacean species even throughout region and depth (Baillon et al. 2014). However, it remains unclear how the observed species abundance compares to sandy subtidal environments lacking these *P. gurneyi* beds. Future research could investigate if

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epifaunal biodiversity is higher within this *P. gurneyi* bed compared to areas within this area that lack *P. gurneyi* colonies.

### Interspecific Interactions

Interspecific interactions (n = 23 total) were observed from multiple taxa. Most of these interactions were classified as being commensal, with one predation event observed. From the literature on Pennatulacean mutualistic or commensal interactions, the role of sea pens are typically as nursery habitats for various *Sebastes* spp., coverage and food for small invertebrates like amphipods and copepods, and microhabitats for filter feeders (Baillon et al 2012, Baillon et al. 2014, Johnstone 1969, Sethi et al. 2022). Other research has shown that fauna are more likely to be “near” Pennatulaceans in general, compared to their more structurally complex and inflexible relatives the gorgonians (De Clippele et al., 2015). This trend is consistent with most of the interactions observed.

The most common interaction observed was between *P. gurneyi* colonies and two fish species: *L. lepidus* (bay goby) and *L. bilineata* (rock sole), n = 16. In these interactions, these fish appeared to use the colonies as coverage from the current as they consistently sat leeward to the current behind the colonies’ peduncles. As the colonies are neither benefiting nor being disadvantaged, these fish may be commensals of *P. gurneyi*. Similar observations have been made of this phenomenon but most often with small invertebrates such as amphipods and shrimps, not mid-sized vertebrates like fish (Johnstone 1969). These observations may serve as additional examples of *P. gurneyi* acting as structural habitat for a variety of taxa.

During one observation night dive, two similar interactions were observed between *M. magister* (Dungeness crab) individuals and *P. gurneyi* colonies (Figure 3). It remains unknown

where these organisms came from and whether they are transients from a rocky reef environment to the *P. gurneyi* bed or are residents to the bed. These crustaceans were exclusively observed at night but it remains unclear if this observation has any significance. The interactions between *M. magister* and *P. gurneyi* could likely be described as commensal since the sea pens do not appear to be benefitting or being disadvantaged by the interaction. Unlike the fish species, both *M. magister* individuals did not appear to be hiding from the current, in fact one was facing directly into it (Figure 3), but with the lack of structural habitat in these environments, they may have been using the sea pen colonies as coverage from predators.

Two observations of *O. gracilis* (graceful decorator crab; Figure 4) and an unidentified crab suggest a mutualistic relationship with *P. gurneyi*. These observations were made on different days, using different methods of observation, however they both occurred at night and captured very similar interactions. These crustaceans both climbed on top of *P. gurneyi* colonies and appeared to climb over their leaves or rest on top. It did not appear that they were feeding on the colony or harming it in any way. They could not have been hiding from the current or from predators and initially it was unclear how they could benefit from exposing themselves on a highly visible platform. However, this is not the first time this strange interaction has been observed.

A similar commensal relationship was seen in *Pagurus hirsutiunculus* (hairy hermit crab) where the crab sat on top of a *P. gurneyi* colony without any apparent feeding occurring or harm to its host (Johnstone 1969). We originally hypothesized that these crustaceans may be feeding off of any detritus covering the sea pen's leaves, but such feeding was not obvious in this or past research (Johnstone 1969). These crustaceans may also be using one of *P. gurneyi*'s defense

mechanisms, a toxin called ptilosarcone, as a sort of coverage from predators (Wratten et al. 1977). Ptilosarcone and the sea pen's distinctive bright coloring likely dissuades generalist predators from coming near them, giving a layer of protection to a delicate organism like *O. gracilis* in a relatively featureless environment (Patel 2018). This may be one-half of a mutualistic relationship. Crabs are opportunistic feeders and may feed off of or scare away any nudibranchs that attempt to feed on their host. However, future research would be needed to support any such claims.

Two photographs of *P. gurneyi*'s predators were taken in this research, but the only predation event observed was by *A. californica* (striped nudibranch; Figure 5). *A. californica* was observed more frequently than any other nudibranch or predator of *P. gurneyi* altogether, but they were often partially or totally buried in the substrate (Personal Observation). This is consistent with past research which notes that *A. californica* spends little of its time on ingestion (Birkeland 1974). The one predation event was observed on a juvenile colony. As *A. californica* is known to exclusively feed on *P. gurneyi*, this observation is not surprising. However, the juvenile sea pen did not utilize its main defensive strategy and contract into the substrate even when its predator was fully on top of it and it appeared to be undamaged (Figure 5).

When one other predator—*T. festiva* (diamondback tritonia)—was observed (Figure 5), it was also near a juvenile colony. While a predation event was not observed in that instance, over the course of the dive, the odds of survival for the juvenile colony were grim as *T. festiva* preferentially and ravenously feeds on small *P. gurneyi* colonies (Birkeland 1974).

## Conclusion

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Continued data collection at this site will be essential to understanding any potential trends in the sea pen density at this site and how to mitigate possible threats against these organisms and the ecosystems they support. The interactions highlighted in this study further illustrate the importance of these organisms even to other epifauna and the need for future research into how and why these interactions occur.

### **Acknowledgements**

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### **Conflict of Interest**

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

### **Data Availability Statement**

Data are not currently available to the public. Available upon request to [katie@seapens.org](mailto:katie@seapens.org).

### **Author Contributions**

The conceptualization, methodology, field work, and review and edits of this paper was done by both contributing authors, KS and DS. All data analysis and writing were done by KS. Supervision and advising was done by DS.

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