

**Tethering as a method for evaluating shrimp predation by San Juan Island rockfish  
(*Sebastes* spp.)**

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## Abstract

Trophic cascades have been shown to completely alter marine communities, especially after the collapse of an important fishery. It is therefore important to understand trophic relationships between marine organisms in order to prevent the drastic change of ecosystem structures due to anthropogenic impacts such as overfishing. In the Salish Sea, rockfish, *Sebastes caurinus* and *Sebastes maliger*, are an important predatory fish that have been in decline in past years. In order to understand the predator-prey interactions of rockfish in the San Juan Islands, we used prey tethering techniques, to assess relative rates of predation on shrimp and how much predation is occurring from rockfish. Coon-stripe shrimp, *Pandalus danae*, were tethered and attached to a frame that was deployed at two sites with different rockfish abundance. A camera was also deployed in order to record video footage of predation. Our method of tethering was successful, showing 100% predation in deployments longer than 18 hours and capturing video footage during the day without the use of an artificial light. Various predators were observed in video data from each site. We recommend that this method be used to assess the rockfish and shrimp relationship in the San Juan Islands and suggest expanding this study to include multiple trials throughout various seasons.

## Introduction

The structure of an ecosystem is driven by interactions between its predators and prey, with population changes in one trophic level being able to dramatically affect the rest of the community, both directly and indirectly (Paine, 1966). Predator depletions have been noted as

having dramatic effects on ecosystem biomass and prey dynamics, and also play an important role in structuring the community (Myers and Worm, 2003; Shears and Babcock, 2002).

Anthropogenic changes in fish population sizes through predator depletions or invasions, can have drastic effects on the ecosystem structure that are observed throughout lower trophic levels (Baum and Worm, 2009). The magnitude of this trophic cascade, and the location of its effect in the food chain, depends on a number of variables including predator diversity and the trophic position of the predator (Bruno and O'Connor, 2005). (Frank et al., 2005) looked at the effects of the cod fishery collapse in the northwest Atlantic on lower trophic levels and found that a trophic cascade did exist. Due to the depletion of cod there was an increase in abundance of small pelagic fishes and some macroinvertebrates and similar cascading effects in the plankton community.

In the northeast Pacific, rockfish are economically and ecologically important bottom fish predators but due to their high commercial demand have been depleted, with the total biomass of major commercial species dropping more than 75% in a 30 year period (Love et al., 2002). In northeast Pacific temperate reefs, there has been evidence of a trophic cascade including lingcod, rockfish, and shrimp, where lingcod predation on rockfish indirectly effects shrimp populations (Frid and Marliave, 2010). In addition, their data suggested that rockfish could play a role in mediating apparent competition between different species of shrimp, indicating that rockfish are also an integral piece to the structure of that ecosystem. In the San Juan Islands, the two most common benthic rockfishes are the Copper, *Sebastes caurinus*, and the Quillback, *Sebastes maliger*, which share very similar niches and act as mesopredators in the community, alongside greenling and young lingcod (Frid et al., 2012; Love et al., 2002; Murie, 1995).

Monitoring ecological processes, such as the predation of rockfish, is a difficult task in the field, but may be achieved through various techniques such as prey tethering. Tethering experiments have been successfully used to measure relative rates of predation or predation intensity in the field with species such as rock shrimp, spiny lobster, and blue crab (Eggleston et al., 1990; Heck and Thoman, 1981; Mintz et al., 1994; Ory et al., 2012; Wilson et al., 1987). In northeast Pacific temperate reefs, (Frid et al., 2012) used tethering experiments to observe how predatory habits of mesopredators changed with the presence of a top predator.

The objective of our project was to observe the predator-prey relationship between San Juan Island rockfish and shrimp, in order to gain a better understanding of the species interactions and their impacts on the community ecology. Due to similarities in environment, ecosystem, and research goals of previous tethering experiments, we decided that tethering would be the best method to assess relative predation on shrimp in the San Juan Islands community. In addition to testing the success of our tethering method, we wanted to know the rate of shrimp consumption and the various predators consuming them. We predicted that shrimp in an area of high rockfish abundance would be primarily eaten by rockfish and shrimp in a low rockfish area would be primarily eaten by other predators such as greenling.

## **Methods**

### *Study site*

Two sites in the San Juan Islands were used in this study, both located on the western coast of Shaw Island. Point George (48.556° N, 122.985 °W) and Neck Point (48.579 °N, 123.014 °W) had been surveyed during the year and observed with low and high rockfish

abundance, respectively (K. Turner, unpublished data; Fig 1, 2). At Point George, the shallow substrate close to shore consisted of a kelp bed and then dropped off to a rocky substrate at about 18-20 m. The bottom substrate at Neck Point had areas of sandy depressions between the rocky cliff off the shore and the rocky substrate at about 18 m depth. Rockfish generally inhabit rocky substrates, so in order to deploy the frame in an area where rockfish may have been present, the target depth at each deployment site was about 18-20 m.

### *Experimental design*

We used tethered prey experiments modeled after previous studies in order to assess relative rockfish predation and diet (Frid et al. 2012, Eggleston et al. 1990, Heck and Thoman 1981, Wilson et al. 1987). All shrimp, *Pandalus danae*, used for this study were caught with nets off the dock at University of Washington Friday Harbor Labs. Live shrimp between 9.0 cm and 11.7 cm (average length: 9.98 cm) were tethered with a monofilament line (4 lb test) by a loop tied around their cephalothorax between the third and fourth legs and secured with a bowline knot. Each monofilament line was attached to a 100 cm cotton line, approximately 25 cm apart from each other (four shrimp per line). The cotton line was secured on the bottom of a 104 cm by 100 cm by 36 cm rebar frame (Fig 4a). Monofilament line was approximately 10 cm in length so shrimp could not reach one another and become tangled together. Shrimp were tethered and attached to the cotton line ahead of time in the lab and were transferred to the boat in buckets with ambient seawater. Individual shrimp were placed in plastic containers with holes to prevent them from being tangled during transport. Dive weights (1.4 kg) were attached to the bottom of the frame to ensure it was held in place on the substrate. A video camera (GoPro) in underwater dive housing was also deployed in order to see which fishes were acting as predators. An extra battery pack was attached to the camera in order to prolong the amount of video footage. The

GoPro was attached to an acrylic plate with its suction cup mount, which was attached to the frame via zip ties (Fig 4b).

### *Data collection*

Between October 19, 2012 and November 15, 2012, a total of 12 frames were deployed, 6 at Point George and 6 at Neck Point. The video camera was attached to each frame for a total of 5 deployments, 3 at Neck Point and 2 at Point George. After we deployed a frame, we left it out for 7 to 77 hours. The GoPro camera was set on time lapse to take one picture every 10 seconds. We analyzed video data to assess what potential predators were present at the frames and, in some cases, we had observations of actual predation events on the shrimp at each site.

### **Results**

Predation on the shrimp occurred at 100% of the frames deployed (n= 12) and on 92% of individual shrimp (n= 48). Average predation on frames that were deployed for less than 18 hours was 50% (n= 2) while average predation on frames that were deployed for more than 18 hours was 100% (n= 10; Fig 6). Average length of deployment was 36 hours.

In time lapse footage from 16 hours of recording, a total of 8 different predatory species were observed: greenling, Copper Rockfish, flatfish, lingcod, *Pycnopodia*, *Pisaster*, sea urchin, and a crab. Per 3 hours of video, the average number of predator sightings at Neck Point and Point George were 6 and 5, respectively (Fig. 7). In all of the video footage, there were a total of 10 greenling sightings at Neck Point, while there were 7 at Point George. At Neck Point, Copper rockfish were observed 6 times and flatfish were observed 2 times, while neither was observed at

Point George (Fig. 8). Some invertebrates were observed around the frames as well. We had 3 lingcod sightings at Point George compared to only one at Neck Point. We observed 2 different substrate types in video footage from Neck Point: sandy bottom and rocky bottom. For the deployment on sandy bottom at Neck Point, we observed a *Pycnopodia* and a flat fish predator on the shrimp. This deployment on sandy substrate at Neck Point was the only video footage where we observed those two predators. In the two deployments on rocky substrate at Neck Point, we observed Copper Rockfish, greenling, urchins, and a crab.

## Discussion

We developed a method to assess relative predation on shrimp in the San Juan Island community in order to better understand the relationship between rockfish and shrimp in the ecosystem. While our sample size was limited due to time and weather constraints, and we could not specifically address our hypothesis, we were able to gather preliminary results that suggest our method is a viable option and has potential for future studies. Our results showing 100% predation when the frame was left out for more than 18 hours indicates that our frame set-up was successful for our tethering experiment (Fig. 6). The predators were not deterred by the frame and were able to approach and eat the tethered shrimp. Since 100% predation occurred every time after 18 hours, a shorter deployment time is suggested in order to get a better measure of the relative predation (Ory et al., 2012).

The GoPro captured adequate footage during the day without the use of an external light which could alter predator behavior (Ryer et al., 2009). When exposing fish to a simulated light source, like that of a submersible vehicle or a video camera, Ryer et al. found that fish responses

to the artificial light varied across species. While sablefish were very reactive and rockfish were mildly reactive, lingcod had no reaction at all. This suggests that an artificial light source used to capture video footage of behavioral data could present biased information. Our video footage at Neck Point showed two different substrate types, and we observed different predators at each. This indicates that the substrate will have an effect on the type of predators that forage on our tethered shrimp. More deployments and video footage will be required in getting more accurate predation counts.

One limitation of this experiment was the immobility of the shrimp leading to predation by atypical predators. Shrimp are generally much too fast to be normal prey items of invertebrates such as *Pycnopodia* (personal observation), but on several occasions in our experiment, *Pycnopodia* came in and foraged the whole line of shrimp. Another disadvantage to tethering experiments is the fact that the 4 shrimp on the line are not independent of one another. It is entirely possible for one predator to come in and eat all 4 shrimp on one frame, just because they are easy prey. These limitations must be considered when looking at data and drawing conclusions from this type of tethering experiment.

Tethering devices have been used as a method of observing predation intensity in various habitats (Frid et al., 2012; Heck and Thoman, 1981; Ory et al., 2012). Experimental duration presumably has an effect on the results of this type of experiment and varies widely across the board (Puntilla et al., 2012). In previous tethering experiments, duration varied from 24 hours, to 4 hours, to as little as 30 minutes (Frid et al., 2012; Heck and Thoman, 1981; Ory et al., 2012). When attempting to assess differences in relative predation intensity, a prolonged experimental duration could cause results to show little difference (Puntilla et al., 2012). In our experiment, the duration of deployment was limited by inclement weather and thus varied from 7 to 77 hours. It

is therefore suggested that future experiments use a much shorter deployment time in order to observe predation intensity differences. In order to avoid this problem of experimental duration, some experimenters have used chronographic tethering devices that record the times of predation events, however, these devices can often be expensive and difficult to assemble (Baker and Sheaves, 2007; Peterson et al., 2001; Puntilla et al., 2012). Another way to avoid the problem of experimental duration is setting up an underwater video camera to record predation events (Frid et al., 2012). Even though the duration was limited by the battery life of the camera, this set up allowed the divers to vacate the experimental reef for 4 hours after the camera was set up. In our experiment, we devised a method that would emulate this while also eliminating the need for divers, in order to cut down on the time required for each deployment and increase the frequency of deployments.

Though we were particularly interested in the relationship between rockfish and shrimp, this type of video footage allows us to observe other predators on shrimp in the same community. While it is assumed that shrimp are an important prey item for many fishes in various communities, little research has actually been done to quantify this importance (Parsons, 2005). To fully understand the relationship between rockfish and shrimp in the Salish Sea, the full extent of shrimp's role in the food web should be further researched.

For future studies, there are many variables which need to be considered. Rockfish have been shown to be most actively feeding during the morning and evening hours (Love et al., 2002). This means that rockfish predation measured by tethering experiments and corresponding video footage could vary depending on the time of day that the experiments take place. It is therefore important to deploy the frames and video camera at a variety of times during the day. In addition to diel changes, various studies on rockfish diet have observed shifts in prey items

from season to season (Love et al., 2002; Murie, 1995). Further indication of these seasonal shifts are found in observations of the Puget Sound Copper Rockfish making seasonal movements of habitat and depth, presumably in correlation with prey availability (Matthews, 1990).

In the case of the San Juan Island community, managing predatory fish populations (i.e. lingcod and rockfish) requires us to evaluate the specifics behind rockfish predation on shrimp. We want to know if the San Juan Island rockfish are eating a lot of shrimp because they are a preferred prey item, or if it is solely because shrimp are in abundance here. If shrimp, for example, are the preferred prey item for rockfish in the area, those trying to manage rockfish populations must consider whether or not it makes sense to create reserves in areas where there are no shrimp. Understanding the shrimp-rockfish relationship, will therefore help determine the best management approach for reserves attempting to maintain rockfish populations. In the same manner, understanding other aspects of the community's trophic relationships, such as the impact of lingcod predation or seasonal predation variances, will also play a key role in successful management of marine reserves (Beaudreau and Essington, 2007; Frid and Marliave, 2010). The complexity of these trophic interactions cannot be understated, and when approaching management issues in the San Juan Islands, it is important look at not only protecting rockfish populations, but protecting the integrity of the community structure in the lingcod-rockfish-shrimp interaction (Frid and Marliave, 2010).

Top-down impacts from predators have been examined in other temperate reef systems in the Pacific using tethering and removal experiments (Shears and Babcock, 2002). Their study of reef communities, specifically the impacts of a dominant sea urchin, off northeast New Zealand provided evidence for the role of predators in determining community structure. This study

specifically looked at differences between marine reserves and non-reserves and demonstrated the value of marine reserves in providing a way to research indirect effects of anthropogenic changes to fish populations and what kind of impacts they can have on trophic structure in an ecosystem.

The successful management of marine reserves requires an in depth understanding of community structure, the various predator-prey interactions, and the effects that one species can have on the entire trophic structure. To take this one step further, ecosystem-based management, which relies on an integration of all the different components that influence marine environments, often requires an even larger ecosystem context that extends beyond the small marine reserves (Slocombe, 1998). Our tethering method, upon many more deployments, will provide a way to gain a better understanding of these trophic relationships by allowing us to observe predation intensity on shrimp.

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## Figures

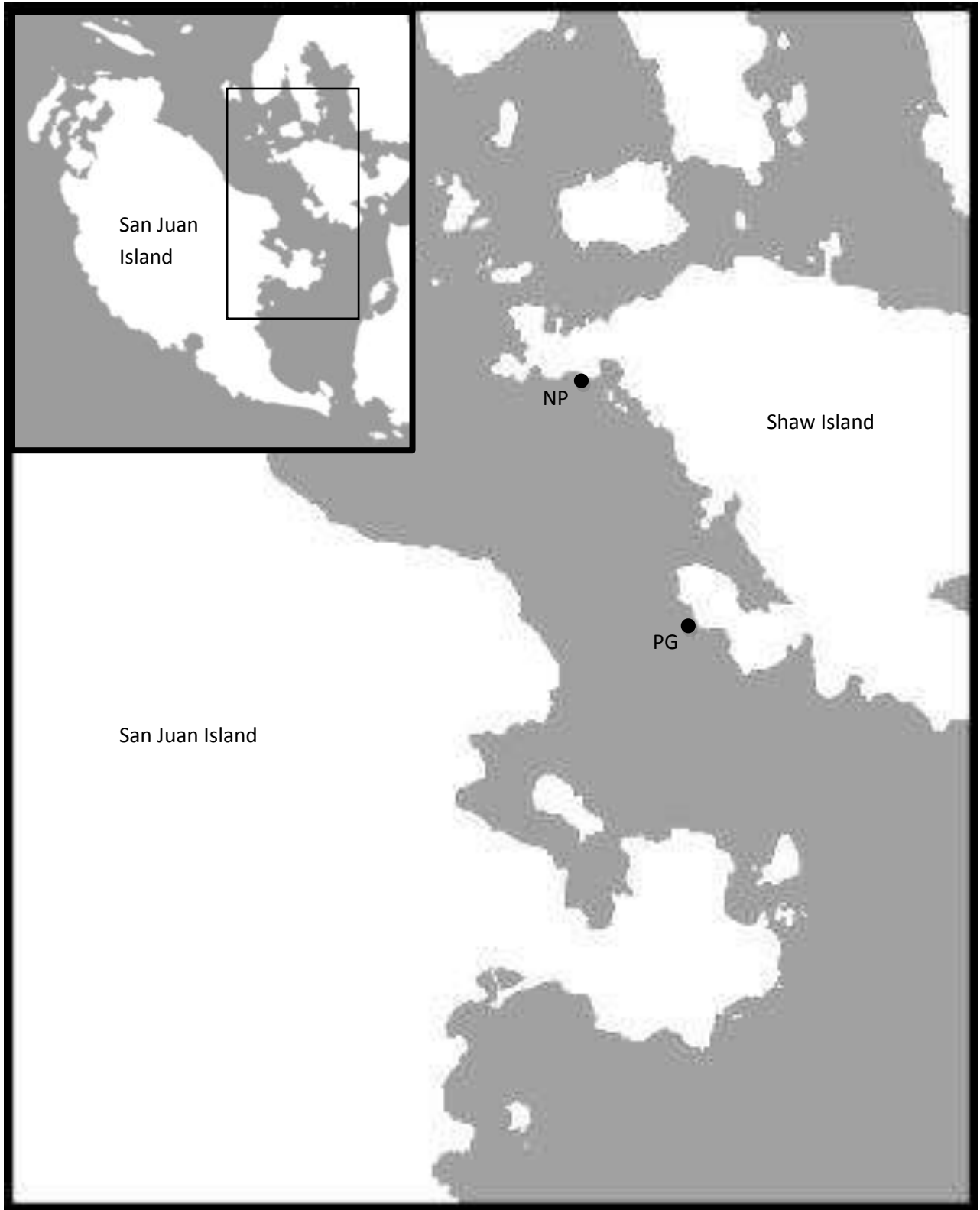


Figure 1: Map of the study sights. Neck Point (NP) 48.579 N, 123.014 W was one deployment site and Point George (PG) 48.556, 122.985 W was another.

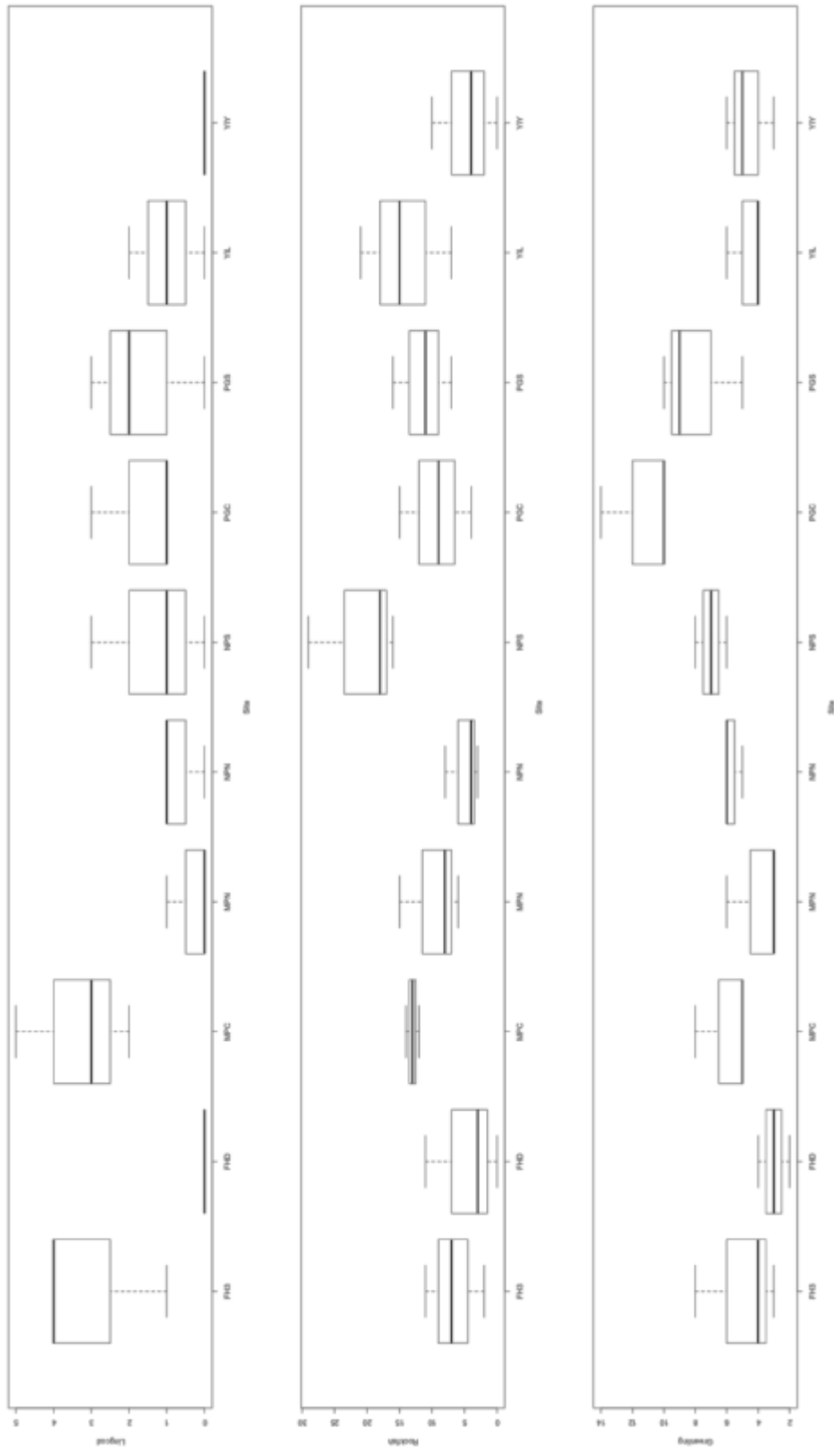


Figure 2: Kevin Turner fish abundance surveys (unpublished data). This box plot shows that rockfish abundance is greater at Neck Point (NPS) than Point George (PGS) and that Point George has a higher greenling and lower rockfish abundance.



Figure 3: Measurement technique for shrimp. Shrimp were measured from the end of the telson to the tip of the rostrum.

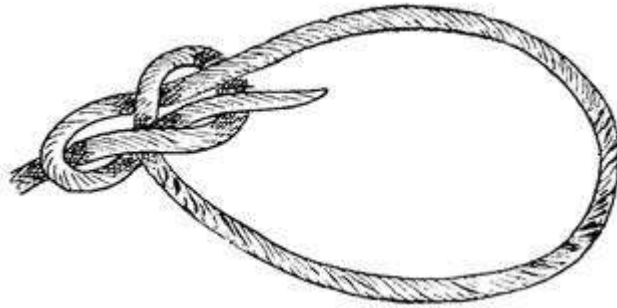


Figure 4: Illustration of the Bowline knot used to tether the shrimp. Monofilament line was tied around the carapace and between the first and second pereopods of the shrimp.

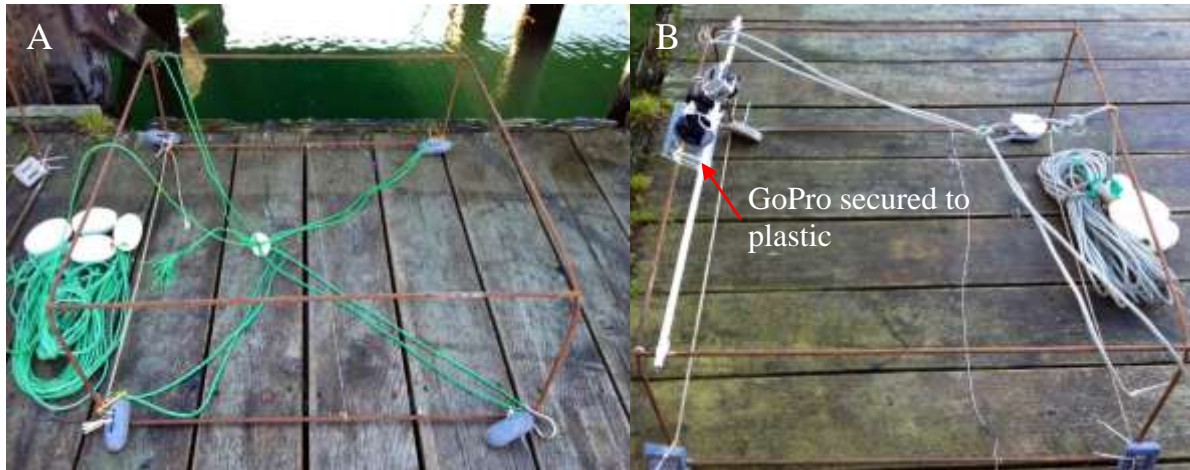


Figure 5: Frame setup without GoPro (A) and with GoPro (B). Rectangular rebar frames acted as the experimental setup. The shrimp tether was attached horizontally to the bottom rung of the frames. A GoPro was mounted on one frame using a suction cup and zip ties (B). The suction cup was secured to a plate of plastic which was secured to the rebar frame with zip ties.

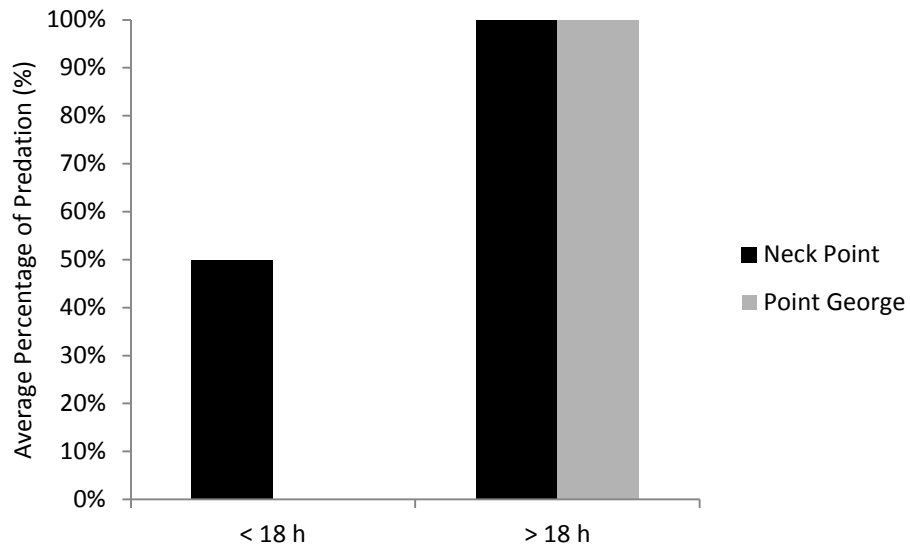


Figure 6: Average predation on shrimp based on the deployment time of the frame. Predation percentages were compared when the frame was left out for less than 24 hours versus 24 hours or longer. Predation was reported as an average percentage of the shrimp gone from the frames when they were recovered at each site. When the frame was left out for less than 18 h, predation was at 50% compared to when the frame was out for greater than 18 h when predation was 100% at both sites.

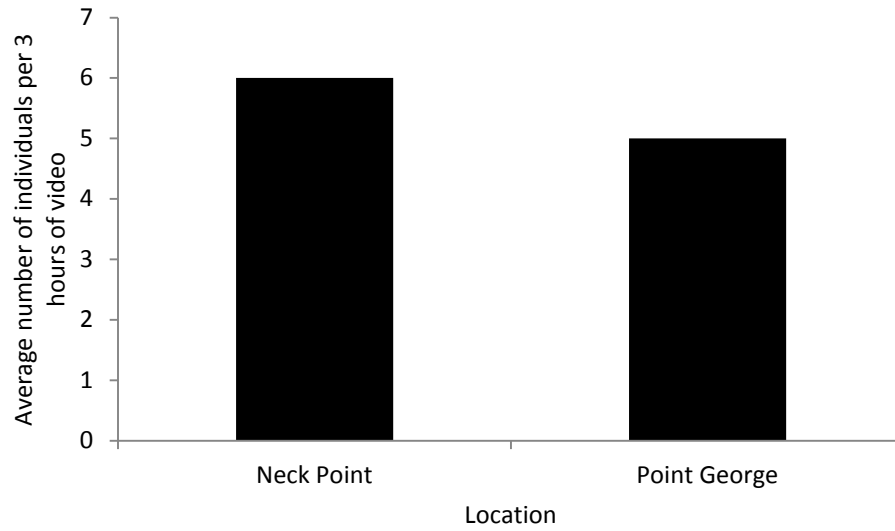


Figure 7: Average number of predators per 3 hours of video at each site. The predators were counted at each site during 3 hours of video recorded during each frame deployment and then averaged. These predator observations account for 15 hours of video data over 5 deployments. The average number of predators at Neck Point was slightly higher than at Point George (6 and 5, respectively).

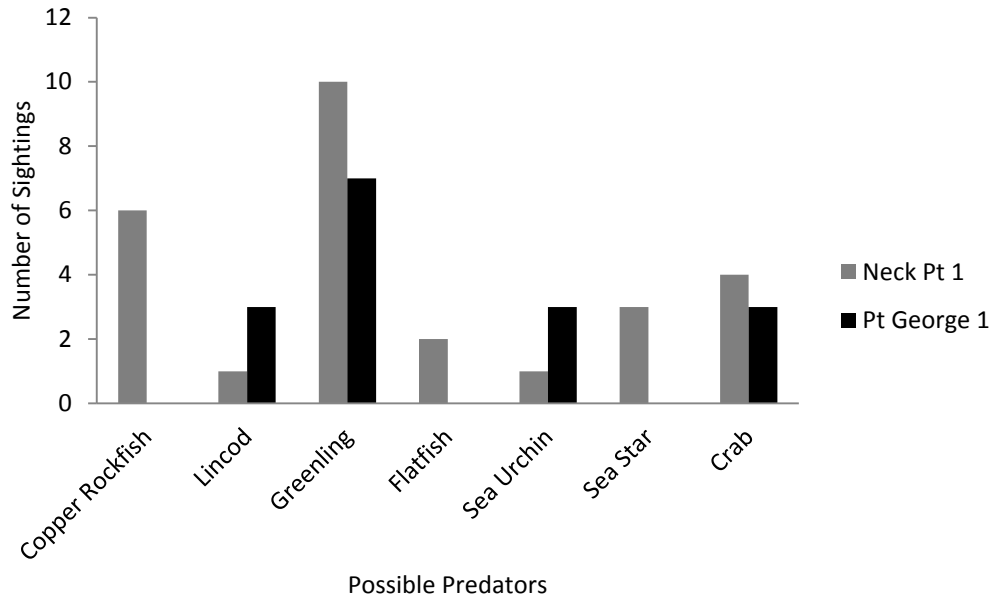


Figure 8: Predators observed in the video footage at each site. The predator sightings were observed through six hours of video data for two deployments at each site. Copper rockfish, flatfish, and sea stars were observed only at Neck Point. The most greenling sightings occurred at Neck Point, but Point George also had greenling. Lincod were observed slightly more frequently at Point George than at Neck Point.

