

The Influence of Salinity and Sea Star Wasting Syndrome  
on Sea Star Species Composition and Distribution in  
Nootka Sound, British Columbia

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## **Abstract**

The effect of salinity and Sea Star Wasting Syndrome on the distribution and composition of sea star species was studied in Nootka Sound. Using an underwater camera survey were conducted over four days the Muchalat, Tlupana and Tahsis Inlets of Nootka Sound. These surveys revealed that not only do the sea stars show a trend in their distribution from salinity, but also that the Inlets may have been struck by Sea Star Wasting Syndrome at some point in the past. These results suggest that the intertidal of Nootka Sound could be changing due to the removal of the keystone predators.

## Introduction

The sea star is an echinoderm that lives in the rocky intertidal of almost every coast. The intertidal is one of the most stressful environments on the planet, as it is the only area where from hour to hour the organisms can be underwater or exposed to the air (Fly et al. 2012). The most prominent species of sea stars in the Eastern Pacific are *Pisaster ochraceus*, *Pycnopodia helianthoides*, *Evasterias troschelii*, and *Dermasterias imbricata*. They often live within the top four meters of the water column, closest to their primary food source which are mussels (*Mytilus* sp.) (Held and Harley 2009). They have also been known to eat practically anything they can find in the intertidal, which makes them an ecosystem regulator. Sea stars have the ability to maintain the ecosystem by eating the organisms that become overgrown, have higher population, or are invasive to the area (Harley et al. 2013); the term for a species like this is a keystone species (Paine 1976; Menge and Berlow 1994). The influence of a sea star in the intertidal ecosystem was investigated by Paine 1976, when he removed the keystone predator *P. ochraceus* from a rocky intertidal area, and by doing so allowed the mussels to take over that ecosystem. When the sea stars were reintroduced the mussels had grown so significantly in that time period that the sea stars could no longer consume them, permanently altering the ecosystem.

Sea stars have adapted to their specific environments due to the stressors of the intertidal ecosystems, such as the differences in substrates and salinities. One such adaptation is that the sea star is a broadcast spawner, meaning that they release their eggs and sperm in clouds into the water during the mating season and they must meet by chance in the water column to form larvae (Menge 1975). This is useful to the sea star because it removes the aspect of finding a mate from the equation and allows them to focus on surviving in the intertidal by staying relatively stationary. Sea stars can live on any type of substrate; from rocks to sand as long as they are capable of remaining fixed (Rogers and Elliott 2012). Their tube feet have adapted to allow the

sea stars to withstand the forces from waves and rolling stones (Santos et al. 2005). Another adaptation is to change their physical appearance to slim down in areas of high wave action in order to receive less force from the waves, making it easier to grasp the substrate (Hayne and Palmer 2013). The sea stars live in fjords, estuaries, and in the ocean, and are capable of living in areas of varying salinities due to their hydrovascular system which acts as a blood system for the organism (Ferguson 1992). This system allows them to rapidly change internal salinity to match the salinity of the surrounding water, and this helps with the problem of dehydration as the sea star experiences rapid changes in salinity due to the tides. This hydrovascular system also helps with water retention when the sea star is out of the water; a combination of shade and this complex system keeps the sea star from experiencing extreme desiccation (Fly et al. 2012).

Recently, Sea Star Wasting Syndrome (SSWS) has struck the Eastern Pacific killing off sea stars from Alaska to Baja California, making it the largest sea star mass mortality event ever observed<sup>1</sup>. Every species has been adversely affected, showing a mortality of up to ninety-five percent in some areas with three exceptions. The three species that do not show symptoms are *Dermasterias imbricata*, *Othasterias* sp., and *Astropecten polyacanthus*. The syndrome is thought to be a densovirus that has been present in the water column for forty years, and has just now begun to attack the sea stars (Hewson et al. 2014). It is unclear what the trigger for this outbreak is, but it is thought that high temperatures is a stressor that can cause it to flare up in certain species (Bates et al. 2009). The syndrome's only limiting agent is the abundance in the water, this factor determines whether a species will contract the syndrome. If there is enough of the densovirus in the water the species that are susceptible will contract the syndrome.

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<sup>1</sup> <http://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/>

Because sea stars play such a critical role in the intertidal ecosystem and have so few natural predators (Paine 1966), their death by SSWS causes an alteration to the ecosystem in the intertidal. After contracting the syndrome the sea stars begin to consume their own tissues, leading to the appearance that the sea star is melting. They form white lesions, then lose their appendages and begin to decay, and are not able to regrow their limbs as they are when they are chopped off (King and Newmark 2012).

Nootka Sound is located in British Columbia, Canada and has three Inlets, Muchalat, Tlupana, and Tahsis. It is an estuary that has not been extensively studied in the field of sea star observation except for one paper. The paper found that the primary species in Nootka Sound were *Pisaster ochraceous*, *Pycnopodia helianthoides*, and *Dermasterias imbricata* (Sewell and Watson 1993). The salinity is highly variable due to the presence of rivers into the estuaries, which can be a challenge if the sea stars are acclimated to the higher salinities (Menge et al. 2003; Held and Harley 2009; Garza and Robles 2010). Estuarine sea stars are more productive in salinities near 20 whereas the ocean sea stars are more productive in salinities of 30, meaning that estuarine sea stars will consume the most mussels and move around the most in salinities around 20. The one trait both types of sea stars have in common is their very low productivity in lower salinities; the estuarine sea stars have the ability to adapt to higher salinities, and the ocean sea stars could adapt to salinities as low as 20 (Held and Harley 2009). There are river influences in every Inlet of Nootka Sound, and this causes a salinity gradient from the mouth to the end of the Inlets. The estuary has major rivers that influence the surface salinity and temperature of the water; such as the Gold River in Muchalat Inlet of Nootka Sound (Pickard 1963).

As Sea Star Wasting Syndrome is spreading through the Eastern Pacific, the rocky intertidal ecosystem is changing and Nootka Sound has not been studied in this context. The abundance and location of the sea stars in the three Inlets of Nootka Sound may be dictated by the presence of SSWS and the salinity of the area in which they are living, and there is likely to be a medium salinity (20-25 PSU) where they are located where it is neither too fresh nor too saline for the sea stars to survive.

## Methods

The survey was conducted in Nootka Sound in mid-December 2014, on the TN316 cruise of the University of Washington R/V *Thomas G. Thompson*. In order to conduct the surveys along the coast line we used the small boat R/V *Weelander*. The main pieces of equipment used for the surveys were the G700SE Ricoh underwater camera, attached to an extendable plastic pole, which could be extended to four meters. Attached on the end of the camera was a 0.33 meter quadrat which acted as a flat surface to position the lens of the camera at the side of a sheer cliff face. The quadrat was only used in Tlupana and Tahsis Inlet after stabilization of the underwater camera became a problem without it when identifying sea stars in Muchalat Inlet. We used a YSI Data Sonde 556, which was calibrated on the cruise to measure the salinity at various depths. A GPS Map 546S was used to track the locations of sea star surveys, and to develop distance measurements. At the end of each Inlet (excluding Tlupana Inlet) a Secchi disk was used in order to determine turbidity of the water.

The study was conducted over four consecutive days in Nootka Sound. We left early in the morning when the tides were relatively high, and they dropped 0.5 meters throughout the day. Sites were picked at random along the coasts of Muchalat, Tlupana, and Tahsis Inlets of Nootka Sound. Once at a site the location was recorded and the salinity was measured at the surface, 1 meter, 2 meters, and 3 meters depth. Drifting for five meters along the intertidal, we examined the area visually and using the underwater camera. If there were no sea stars in the area, the salinity, GPS location, and the absence of sea stars were recorded and we moved to the next location. When a sea star was found, it was photographed using the video feature of the underwater camera. We continued until there were no more visible sea stars and the GPS was recorded in order to obtain a start and end location.

Upon returning to the R/V Thompson the videos were uploaded and analyzed. The species of sea star were recorded and the sea stars were checked for any signs of the Sea Star Wasting Syndrome. The criteria used to determine if the syndrome was present were as follows (in order from most apparent to least apparent): missing limbs, degraded tissue, white lesions, and “deflation” of the central disk.

The number of sea stars was also recorded in order to determine their abundance over the areas analyzed. The formula used to determine the abundance of sea stars in Nootka Sound is as follows:

$$\frac{\text{Number of Sea Stars}}{\text{Meters travelled} * \text{Depth of deepest Sea Star}} = \text{Sea Stars/Meter}^2 \quad (1)$$

With meters travelled calculated from the start and end GPS of the locations where sea stars were observed.

In order to determine the species of sea star, the videos were analyzed a second time upon returning to the University of Washington, where the species were cross referenced with the website sea stars of the Pacific Northwest<sup>2</sup>. All of the salinity data, GPS data, and sea star data were compiled in order to see the effects of the salinity and SSWS in distribution and composition of the sea stars in Nootka Sound.

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<sup>2</sup> <http://seastarsofthepacificnorthwest.info/species.html>

## Results

In Nootka Sound in mid-December the influence of rainfall is very high due to the input from the rivers leading into the Sound which is at its highest in Winter (Pickard 1963). This was observed in our study with very high gradients of salinity in all the Inlets (Fig 1a). The only Inlet that did not show this gradient was Muchalat Inlet, which was extremely brackish along its entire length due to the large input from Gold River. It is also important to note that Muchalat Inlet was also extremely turbid with sediments discharged from Gold River. Using a Secchi disk it was determined that the visibility in Muchalat Inlet was only 1.5 meters, which greatly inhibited the ability to find the sea stars visually, and we had to resort to the underwater camera only. The Secchi disk revealed a visibility of 9 meters in Tahsis Inlet; Tlupana Inlet was not measured for turbidity but it was observed as being similar in clarity to Tahsis Inlet. In Tlupana and Tahsis it were more saline at the mouth of the Inlets and gradually become fresher the closer they got to the end of the Inlets. The Inlets were influenced by the input of smaller streams that flowed into the Inlets as well, which kept the surface of each Inlet relatively fresh despite the proximity to the mouth of the Inlets, only showing a maximum salinity of 25 (Fig 2). The presence of sea stars in the Inlets was highly influenced by the salinity. Muchalat Inlet, being the least saline Inlet, had no sea stars observed in the intertidal, whereas the other Inlets had sea stars, which were focused almost entirely around the mouth of the Inlets (Fig 1b). There were no sea stars observed below a salinity of 10 (Fig 2). Also it is shown that the sea stars were observed in every salinity above that threshold in Nootka Sound, but there were also areas where the salinity was higher than ten but there were no sea stars present.

The large majority of sea stars observed were *D. imbricata* (Fig 3). The second most abundant species was *A. miniata*, but it was only observed in one location in Tahsis Inlet. *P. ochraceous* was the least observed species and was only seen in two locations; once in Tlupana

Inlet, and once in Tahsis Inlet. *D. imbricata* was observed at every location where sea stars were present in this study, making them the dominant species in the intertidal of Nootka Sound.

Figures

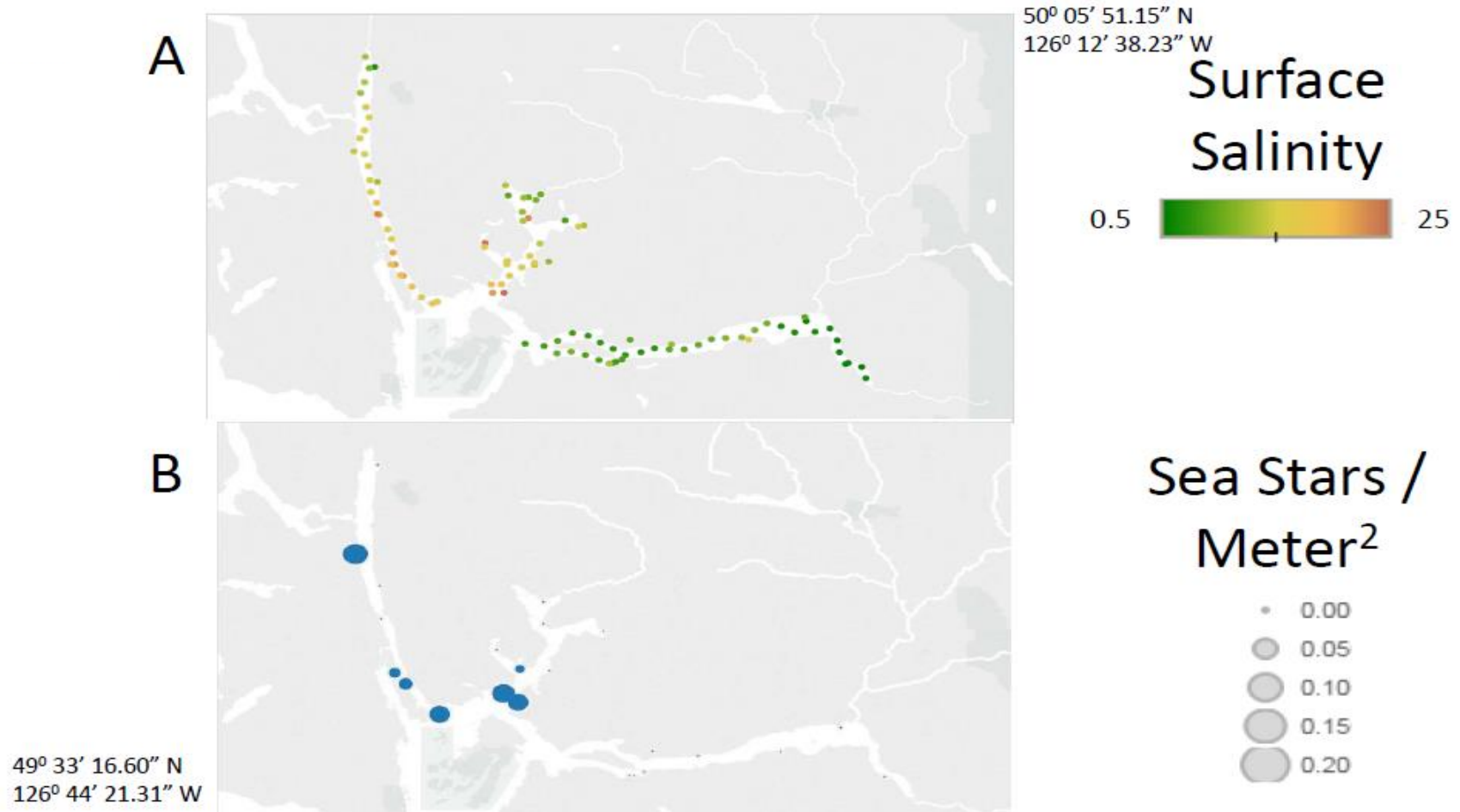


Figure 1. (a) The gradient in salinity in the various Inlets of Nootka Sound. (b) The abundance of sea stars per meter squared at the survey locations.

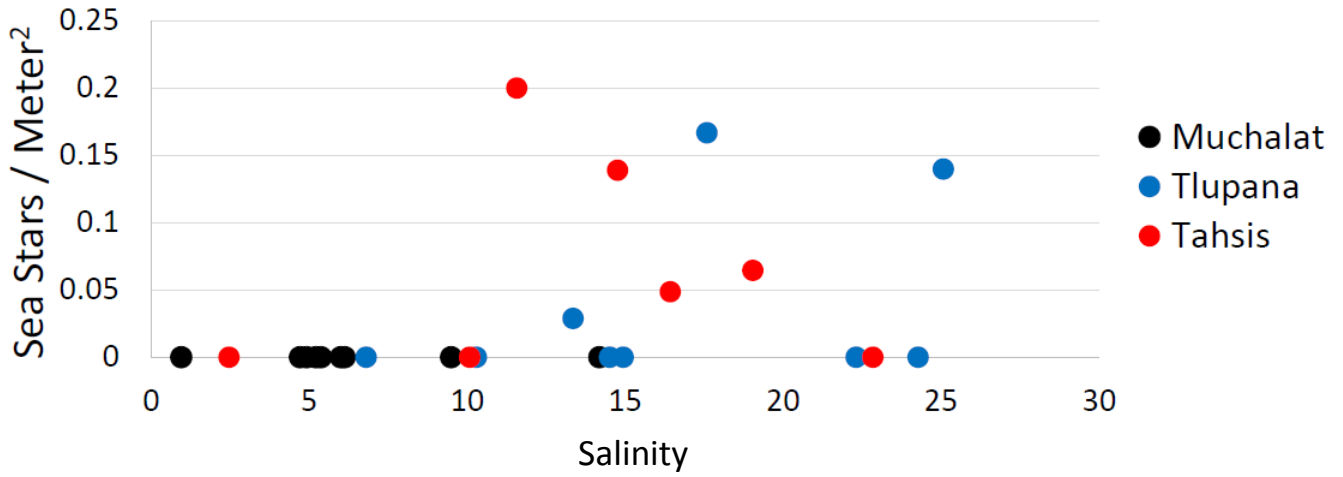


Figure 2. The distribution of sea stars based on salinity in the various Inlets.



Figure 3. The variation in species in Nootka Sound, with a large majority being the *D. imbricata*.

## **Discussion**

Nootka Sound, British Columbia is a site of highly dynamic salinities and the likely presence of Sea Star Wasting Syndrome. The salinity affected the presence of sea stars due to their tolerance to varying salinity; the wasting syndrome narrowed the amount, and changes the species composition. Together, these two factors changed the intertidal in the Inlets of Nootka Sound, because of their removal and dispersal of the sea star species.

### Salinity

The salinity of Nootka Sound is similar to other estuaries in that it has a gradient from the mouth of the Inlet to the end of the Inlet due to the input from rivers. An interesting discovery in this study was the surface salinity in Muchalat Inlet, which maintained a salinity of 15 or below, due to the huge freshwater input from Gold River (Pickard 1963). This has a profound effect on the ecosystem of the Inlet as the sea stars do not live in areas with such low salinities (Garza and Robles 2010). The tolerance for sea stars in an estuary extends as low as a salinity of 15 (Held and Harley 2009); the highest sea stars per meter squared observed was in an area of around a salinity of 12, however the overall quantity of sea stars in that location was only three, the survey was short, raising the sea stars per meter squared. Muchalat Inlet had an average surface salinity below 10 which could account for the absence of sea stars. In the Held and Harley 2009 experiment they found that a *P. ochraceus* would eat two mussels at a salinity of 15 over the course of 72 hours, whereas in a salinity of 20, they eat 5.5 in the same time period. Using the amount of mussels eaten as a proxy for activity, the sea stars in a salinity of 15 were not performing at the rate needed to maintain their dietary needs to survive (Held and Harley 2009). In a salinity of 10 or less they would likely fare even worse, and this is also indicated in our study; there are no sea stars observed in a salinity below 12. This explains why the sea stars

were observed almost entirely around the mouth of the Inlets as it was the area where it was the most saline.

The effect of removing the sea stars from fresh areas allows for the ecosystem to go unregulated by the keystone predators, allowing mussels to overtake the intertidal. This was observed heavily in Muchalat Inlet where *Mytilus* was the predominant species in the intertidal. Because the sea stars may be absent from those areas for long periods of time in Winter due to the high input of freshwater it could provide a potential refuge from predation for the mussels from the sea stars. The ecosystem is affected because when the sea stars leave the intertidal the mussels have the unrestricted capability to grow beyond the sea stars capacity to eat them (Paine 1976). This is called size limited predation and causes a huge alteration to the ecosystem when a keystone species such as sea stars are removed (Menge et al. 1994).

Another parameter to keep in consideration for the Inlets was the water quality. In Muchalat Inlet it was very silty due to the sediment flow from Gold River. It has been shown in multiple studies that the effect of silt on invertebrates is often lethal. The influence of the silt on invertebrates with exposed gills (such as sea stars) results in damage to the gills by the silt making respiration more difficult or impossible. The literature suggests that benthic invertebrates have a mortality rate of 50-85% depending on the amount of suspended sediment and the duration that it is in the water column (Newcombe and MacDonald 1991).

### Sea Star Wasting Syndrome

The species variation in Nootka Sound could have been influenced by the presence of SSWS, as the large majority of sea stars found were *D. imbricata*, which have been shown in testing to be immune to the symptoms of the SSWS (Hewson et al. 2014). *A. miniata* and *P. ochraceus* in Nootka Sound have not fared as well in the intertidal. *A. miniata* was isolated to

one location in Tahsis Inlet and *P. ochraceus* was only found in two locations, once in Tlupana and once in Tahsis. The species composition is most likely due to the presence of the syndrome. Although the syndrome was not observed first hand, it can be inferred that the syndrome played a large role in the species diversity of Nootka Sound. In 1993 the primary species in Nootka Sound was *P. ochraceus* (Sewell and Watson 1993), now it is overwhelmingly *D. imbricata*. The most recent outbreak of the SSWS may not have been the main culprit to this huge diversity change, as other forms of wasting disease influenced highly by the temperature of the water have been observed in the nearby Barkley Sound (Bates et al. 2009). In Bates et al. 2009 they discovered that a wasting disease became highly infectious and prominent in Barkley Sound when the water temperatures rose above 14<sup>0</sup>C. The water in the Winter months in Nootka Sound was less than 14 degrees; however the highest temperatures of the water in Nootka Sound in the Summer can reach up to 20 degrees Celsius. The Bates study shows that the influence of environmental stressors affect the spread of SSWS. Potential stressors can include physical factors such as the temperature and the salinity. The salinity variation in Nootka Sound is extremely dynamic as discussed above. Another stressor is the availability to hide from the sun to decrease desiccation, Nootka Sound has extremely shear intertidal rock faces with few crevices for sea stars to hide from the sun, which is their primary defense mechanism to desiccation (Fly et al. 2012). It is indicated by our data at some point in the past that the stressors exhibited in Nootka Sound were enough to allow the sea stars to become highly susceptible to the syndrome, potentially killing off majority of *P. ochraceus* and *A. miniata* in the area and leaving *D. imbricata*.

## **Conclusion**

The environmental effects that come along with a species shift of this magnitude in the Nootka Sound cannot be readily determined. Further study in the intertidal of Nootka Sound is required to show the long term effects of the SSWS. There were juvenile *P. ochraceus* observed in our study, showing that the species may be reemerging into Nootka Sound after being almost wiped out by wasting syndrome. The presence of sea stars further up the Inlet would be interesting to look in to in the later months of the year and in Summer when the input from the rivers is not as high as in December. Beyond this, the influence of the salinity variation and absence of sea stars should be measured against the number and size of *Mytilus* in the varying Inlets. The progress of *D. imbricata* in the Inlets would also be interesting to analyze as they are the dominant species now, but in a couple years the dynamic of the wasting syndrome may change, and the species of sea star in the Inlet may be something else entirely. Through salinity gradients and the likely presence of Sea Star Wasting Syndrome it has been shown to have an effect on the sea star composition and distribution in Nootka Sound.

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