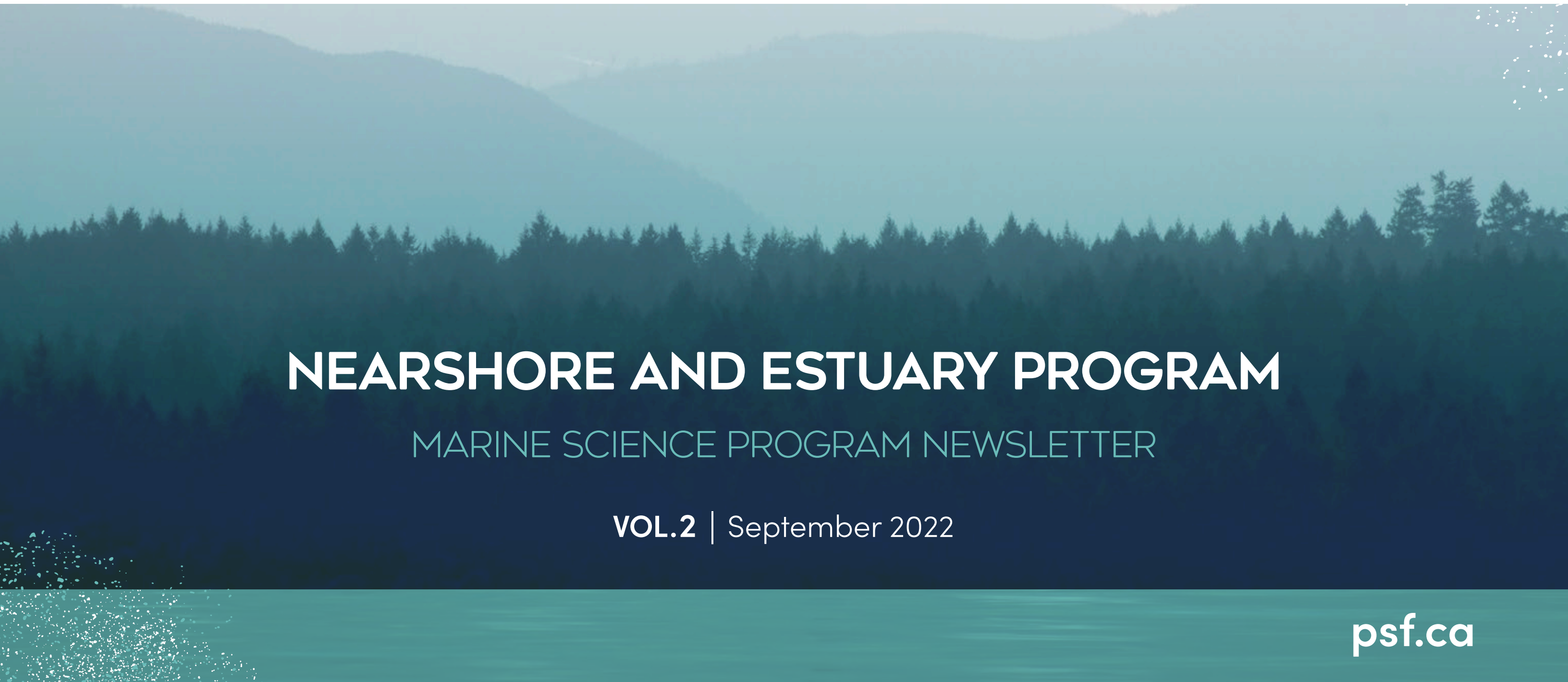
PACIFIC SALMON FOUNDATION



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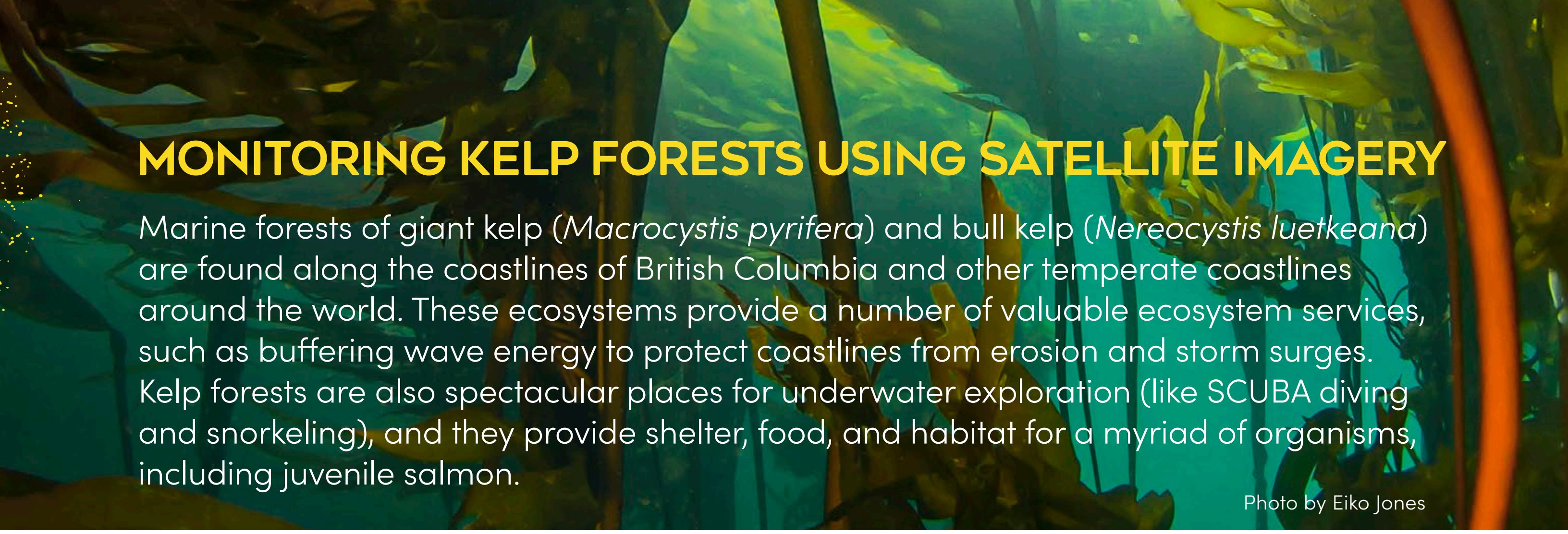

MONITORING KELP FORESTS USING SATELLITE IMAGERY

Marine forests of giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*) are found along the coastlines of British Columbia and other temperate coastlines around the world. These ecosystems provide a number of valuable ecosystem services, such as buffering wave energy to protect coastlines from erosion and storm surges. Kelp forests are also spectacular places for underwater exploration (like SCUBA diving and snorkeling), and they provide shelter, food, and habitat for a myriad of organisms, including juvenile salmon.

Photo by Eiko Jones

Unfortunately, many kelp forests are experiencing declines including anecdotal observations along the BC coast. As with many things in the natural environment, the reasons for declines are complex and varied. For example, overgrazing by sea urchins, marine heat waves, increasing sea surface temperatures, and anthropogenic pressures may be contributing to these losses. Knowing the current status of kelp forests as well as how it has changed through time provides crucial information about the health of the marine system. It is only with this knowledge that we can identify areas that are at risk and act accordingly.

For this reason, the BC Kelp Resilience team at the Spectral Lab of the University of Victoria — Dr. Alejandra Mora, MSc Sarah Schroeder, and led by Dr. Maycira Costa — is mapping the changes in the extent of bull kelp forests using high-resolution satellite images and associated drivers of those changes. The team, which is part of the PSF Marine Science Nearshore program, has focused on kelp canopies from Galiano Island to Southern Vancouver Island in the Salish Sea looking for changes that have occurred over the last two decades.

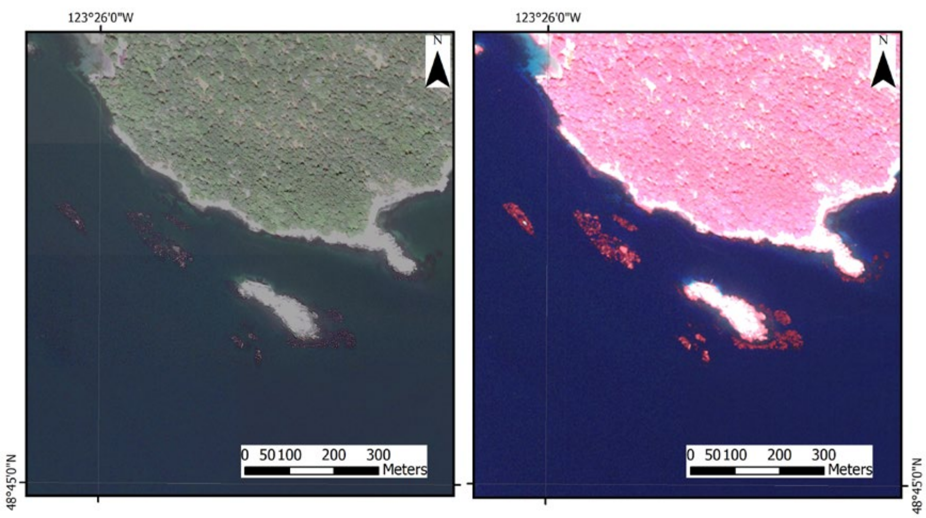

Figure 1: *These satellite images of Fulford Harbour, Salt Spring Island, demonstrate how the team detects kelp forests. On the left is a composite image made with visible bands (red, green, and blue), and on the right is another composite image, but made with infrared, red, and green bands. In the image on the right, the bull kelp canopies can be clearly identified by the bright red patches that stand out against the water.*

METHODS TO DETECT KELP FROM SPACE

The team uses high-resolution satellite images to detect patches of fronds and bulbs (also called blades and pneumatocysts) to define the area of kelp forests. Satellite images have similarities and differences to images from a standard camera. Like a standard camera, the level of resolution determines the number of details that can be detected in an image. Quite different is how satellite sensors 'see' — or collect information. The way a standard camera 'sees' is a combination of three visible bands (red-green-blue), whereas satellite sensors 'see' at spectral ranges beyond red, such as red-edge and infrared, which are non-visible areas of the electromagnetic spectrum. These reflecting signals are crucial to separating kelp from water (Figure 1). Photosynthetic organisms like plants and brown and green algae reflect a lot of light in the red-edge and infrared ranges, whilst water absorbs that light almost entirely. These properties make it possible to easily delineate the two by a digital mapping tool, and this is the basic approach to mapping kelp in the marine environment.

The team is very careful to avoid the omission of kelp that is mistakenly identified as water and the inclusion of kelp where it is actually another plant or algae. This is more challenging for fringing kelp forests along the coastline that are common in some areas of the Salish Sea. It is more difficult to define canopies of these ribbon-like kelp forests in the satellite images with the mapping tool than broader deeper patches. Tides are another complicating factor. Kelp fronds quickly disappear under high tides and strong currents and can be almost invisible from the satellite's point of view. For these reasons, the team classify images acquired from late summer (July to August) at the lowest tide possible and use a very detailed land mask to avoid including other elements that are not actually kelp. These considerations allow the team to be as accurate and complete as possible.

Cover photos by Mitch Miller, Eiko Jones (left), Alejandra Mora-Soto (centre) and Nicole Christiansen (right)

TELLING THE STORY OF KELP IN THE SALISH SEA

Condition Clusters:

Kelp thrives in cold water and wave-exposed areas, although it can adapt to conditions such as warmer temperatures and lower salinity. In the Salish Sea, freshwater inputs from rivers are mixed with ocean water, so kelp forests are located in a gradient of environmental conditions. Therefore, the natural fluctuations of kelp can vary depending on where they are found and the local influences there.

To better understand how different areas of kelp forests are faring through time, the team classified the coastline of their study area into clusters of similar environmental conditions. Factors including temperatures, tidal amplitudes, or exposure to waves were considered in determining the clusters. This step was fundamental to comparing kelp forests from the most to least suitable areas and their patterns of resilience.

The team identified and mapped four distinct clusters (Figure 2)**:**

- **Cluster 1**, are the coldest, most oceanic, and wave-exposed oceanic areas. Here, kelp forests have the largest extent.
- **Cluster 2**, are areas that experience cold water temperatures but are less exposed areas than Cluster 1.
- **Cluster 3**, are warmer and more turbid areas receiving high sedimentation rates from the plume of the Fraser River.
- **Cluster 4**, are protected coastlines with warmer temperatures than Cluster 3.

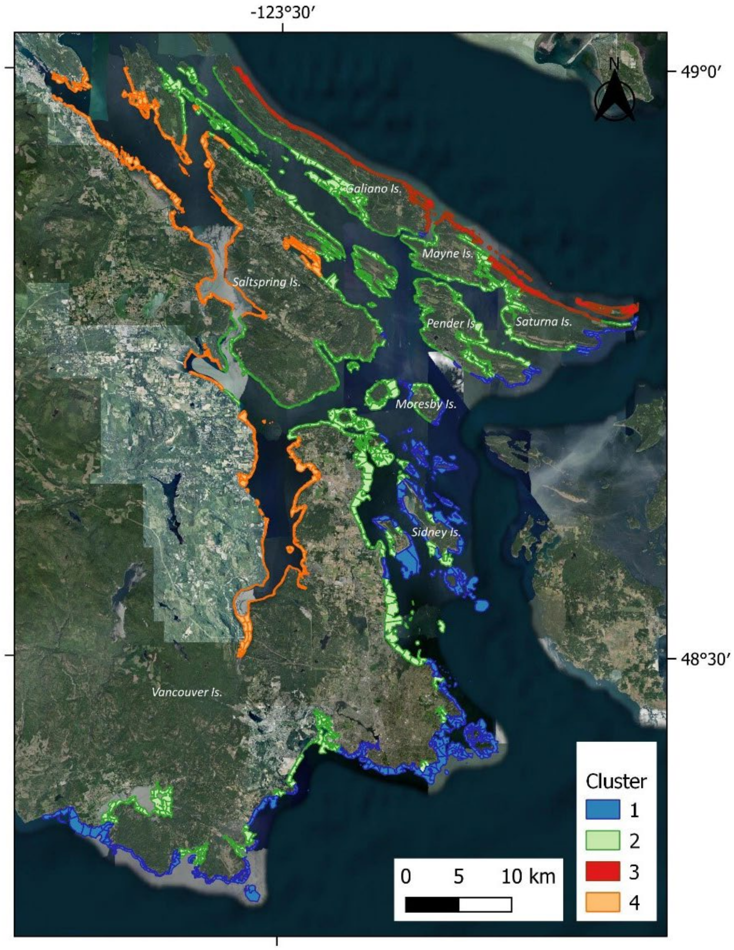

Figure 2: *Distribution of clusters in the study area. Background image: ESRI.*

Kelp Distribution Patterns:

In mapping the locations of kelp forests over the last 20 years, the team discovered that kelp forests are often growing in the same spots from year to year. These areas, called kelp niches, have on average a canopy cover of approximately 25% to 35% at their peak in summer (Figure 3). Bull kelp has an annual life cycle which means that during summer, their reproductive lamina called 'sori' fall apart from the canopy towards the edge of the forest, releasing spores that will germinate and grow during the rest of the year. The area in which new kelp will germinate depends mainly on the presence of favourable conditions on the sea floor, like a rocky or mixed substrate.

Within each of the four distinct clusters of environmental conditions (Figure 2), the kelp niches seem to follow a pattern. Cluster 1 (blue) has the most abundant and most extensive niches, followed by Cluster 2 (green), 3 (red), and then Cluster 4 (orange), which has very few niches. In the study area, the optimal conditions for kelp growth are found in the more wave-exposed and colder areas near the Juan de Fuca Strait. Conversely, where waters are warmer and calmer, for example, near Cowichan Bay (Cluster 4), conditions are less ideal.

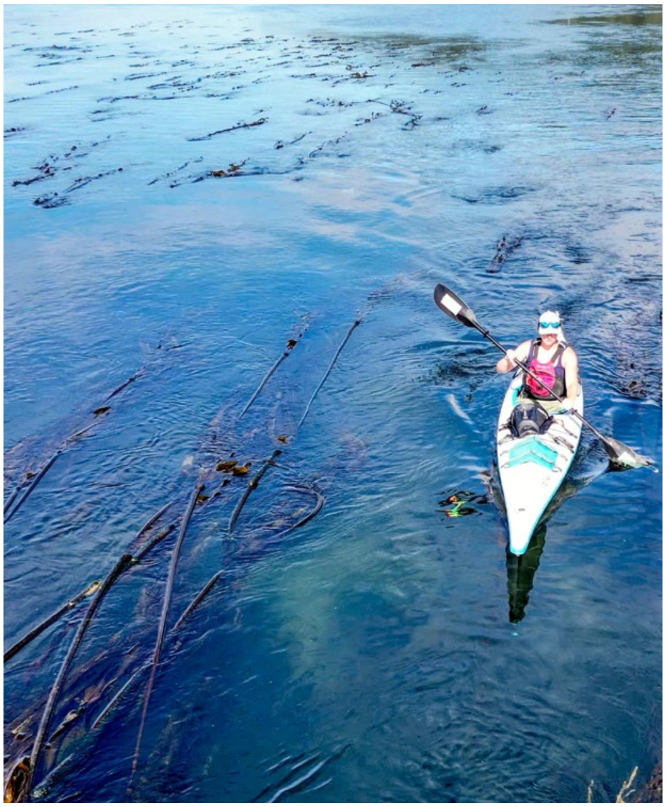

Figure 3: *Sarah Schroeder ground truths areas of bull kelp canopy in a niche that had been mapped via satellite imagery in False Narrows, Gabriola Island.*

Resilience and Recovery:

From 2014 to 2017, areas of the Pacific Ocean including the Salish Sea experienced an extreme and prolonged marine heat wave — famously known as 'the blob'. The extent of kelp, which prefers cooler conditions, declined during this period of highly stressful conditions. After conditions returned to more typical seasonal temperatures, the team was able to trace the recovery of the kelp forests in each of the clusters. After the initial decrease in the size of the kelp forests across the study area, each cluster had a unique temporal pattern of resilience and recovery. Kelp niches in Cluster 1, the more wave-exposed oceanic areas returned slowly, taking approximately 6 years to return to normal conditions. Cluster 2, characterized by cool but more protected waters, recovered more quickly and the niches even increased in size in two years. The niches of Cluster 3, which were generally small kelp forests that experience higher temperatures and receive constant turbidity from the plume of the Fraser River, have continued to decrease. The team has not been able to draw definitive conclusions about Cluster 4's recovery due to the small number of niches and their tiny extent.

NEXT STEPS AND POSSIBLE MANAGEMENT ACTIONS

A canopy of bull kelp on the sea surface is an indicator of how well an ecosystem is doing underwater. The presence of kelp firstly suggests that suitable healthy conditions are allowing it to grow. Secondly, the kelp provides habitat for many species. A lack of kelp from a suitable environment may indicate that something is out of balance. For example, the prolonged marine heatwave may have pushed temperatures beyond kelp's thermal tolerance and other more thermally-tolerant species may have out-competed the kelp. In many regions of the world, the shift from large to small kelp canopies is indicative of an explosive number of urchins feeding on kelp. Observations of 'urchin barrens' where urchins have grazed entire forests down to bare substrate, have been noted on the west coast of North America and have led to cascading effects on other species. Many suspect that the loss of the predatory sunflower seastar due to wasting disease may have facilitated either a change in behaviour of the urchins or resulted in their proliferation and subsequent impacts on kelp forests. Given that the areas in Cluster 3 are constantly decreasing, the team aims to look more deeply in those subaquatic areas to determine what might be causing the losses (Figure 4).

On the other hand, bull kelp is only one of many kelp species living in the same niches. For instance, the increase in bull kelp canopy area in Cluster 2 may indicate that it has gained more space at the expense of other species. Perhaps bull kelp in Cluster 2 are showing more thermal tolerance than other algae in the same area. This is speculation for the moment, but we already know that bull kelp has shown genetic adaptations to local conditions (see Nearshore Newsletter Vol.1).

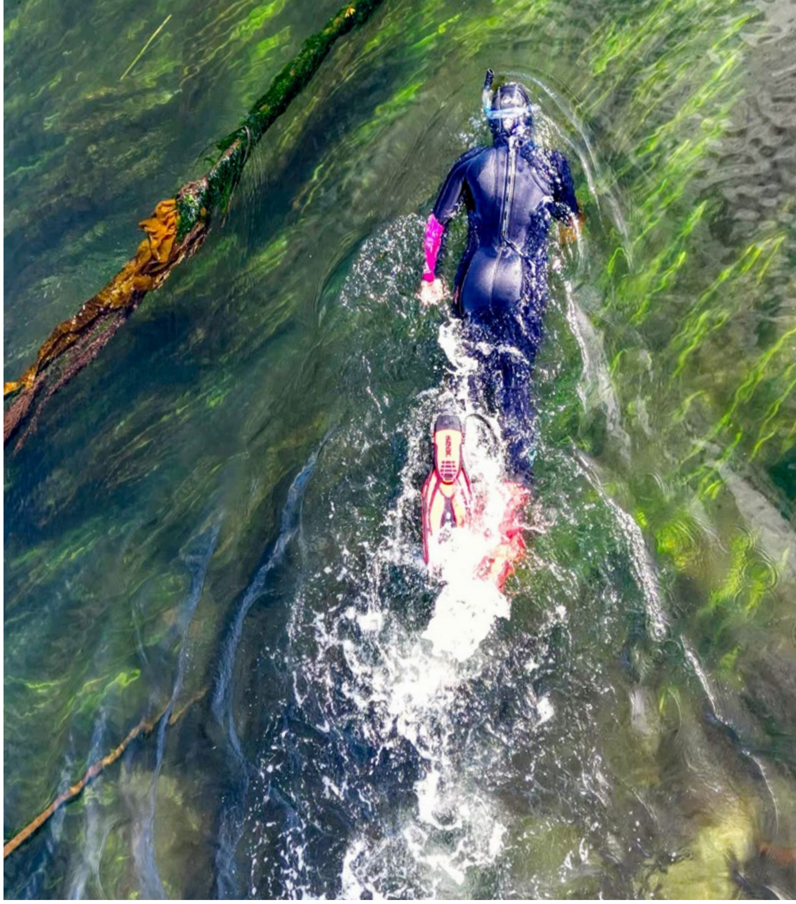

Figure 4: *Alejandra Mora-Soto explores by snorkelling areas of seagrass among kelp at low tide in False Narrows, Gabriola Island. This area has a strong current flow, which seems to be a great factor in keeping bull kelp and their ecological community healthy, although some invasive species like sargassum were also observed.*

With the summer of 2022 being cooler than average, the team is excited to evaluate how bull kelp responded to the more favourable conditions. Particularly with the previous summer exhibiting higher coastal ocean temperatures, the team is wondering how the two years will compare. Did the forests return to their average extent? Or are they still struggling? And finally, the team is looking to identify candidate areas that can be continuously monitored — acting as kelp sentinels of the Salish Sea — and which areas would be best for focused restoration efforts. There are many questions that the team is considering and will continue to work to address. Stay tuned for updates on this critical study!

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