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Vignette 21: How Ecological Time-Series Inform Response to Stressors

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HOW ECOLOGICAL TIME-SERIES CAN INFORM ON THE VULNERABILITY OF DIFFERENT MARINE SPECIES TO MAJOR CLIMATE STRESSOR EVENTS

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An important part of biodiversity monitoring includes assessing the differences in vulnerability across parts of an ecosystem. Hypoxia is one of the big three climate-related stressors causing biodiversity loss in the oceans. As the ocean warms, its capacity to hold oxygen becomes reduced. At the same time, concurrent shifts in circulation result in changes to how oxygen gets transported from the surface (where oxygen dissolves into the ocean) to the seafloor and from offshore to inshore areas. When a habitat experiences a substantial drop in oxygen, below the point needed to sustain everyday life, animals respond by migrating away, adapting to the new conditions, or dying from suffocation. The key to linking the biodiversity response to the oceanographic change is to simultaneously monitor both because high levels of variability are intrinsic to both sides in the ecology equation.

Since 2006, Ocean Networks Canada (ONC) has continuously collected oceanographic data at their Victoria Experimental Network Under the Sea (VENUS) observatory in Saanich Inlet, British Columbia, Canada (https://www.oceannetworks.ca/). ONC operates several of these permanently powered, cabled seafloor observatories in the Salish Sea. Real-time data are captured every minute and streamed to the internet for free public access. The Saanich Inlet VENUS observatory was the first to go online and has since become the longest continuous time-series among seafloor observatories worldwide. At launch, this new technology captured just how variable the annual oxygen cycle was in the Salish Sea and would eventually reveal the decline in the average oxygen level after 15 years of monitoring (Figure 1). A companion biodiversity time-series was also developed alongside the ONC time-series and used remotely operated vehicles (ROV) equipped with onboard high-definition cameras and oxygen sensors to monitor the benthic fish and invertebrate community living in this habitat. With both time-series in place, the first eight years established a benchmark period that showed how seasonality in the Salish Sea creates annual cycling of habitat compression and expansion in Saanich Inlet (Chu & Tunnicliffe 2015). In 2016, this ecological monitoring program allowed an unprecedented collapse in the community to be captured and linked back to an extreme marine heatwave in 2016 (i.e., the Blob).

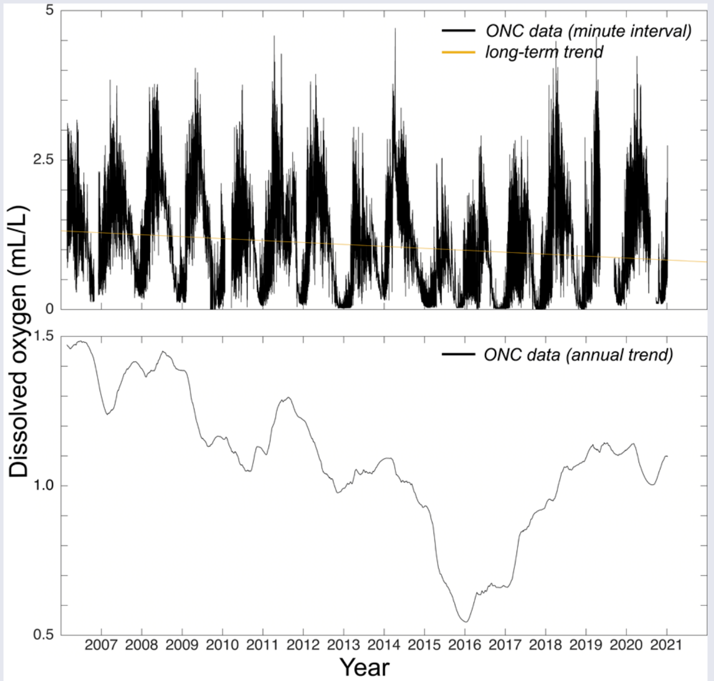

Figure 1. Long-term oxygen time-series from the Ocean Networks Canada cabled, seafloor observatory in Saanich Inlet, British Columbia, Canada. The 2016 severe hypoxia event can be appreciated from looking at the annual trend (one-year running mean) through the raw ONC data and the resulting impacts on the benthic fish and invertebrate community. Source: Open data from http://oceannetworks.ca.

When the extreme marine heatwave occurred in 2016, it had the cascading effect of creating an equally severe hypoxia event in the Salish Sea (Gasbarro et al. 2019). Measuring the impact of this severe hypoxia event was only possible because of the benchmark period and the continued efforts to monitor the fallout for several years after the event had passed. The first sign that the community had reached a tipping point came from the commercially targeted species living in Saanich Inlet. Shrimp such as spot prawn (*Pandalus platyceros*), pink shrimp (*P. jordani*), and humpback shrimp (*P. hypsinotus*) were common in the annual surveys until they disappeared in 2016. Traits of commercially targeted species are often correlated with having a higher sensitivity to hypoxia stress (Chu & Gale 2017). While the shrimp are known to be hypoxia sensitive, they had never entirely disappeared from this site before. Other species, such as those that fishers refer to as "trash species", remained numerous. Populations of squat lobster (*Munida quadrispina*) and slender sole (*Lyopsetta exilis*) remained high and expanded their distributions into the hypoxic areas that usually harboured all the shrimp. All animals need oxygen to survive, but some are physiologically adapted to have higher hypoxia tolerance. Generally, low metabolic demands in squat lobster and slender sole allow them to survive exposure to conditions that are lethal to other species (Chu & Gale 2017; Tunnicliffe et al. 2020). Besides these outliers to the general hypoxia rules, the populations of most other species shrank. The decrease in population density, the absence of shrimp, and the loss of associated species interactions led to a general collapse in the community structure due to the severe hypoxia event (Gasbarro et al. 2019). In 2018, two years after the severe hypoxia event, oxygen conditions returned to normal, and the shrimp returned in abundance. However, the population of what was the most common species at this site, the cold-water coral *Halipteris willeomesi*, continued to decline.

Before 2016, *H. willeomesi* was consistently the most abundant animal observed in Saanich Inlet and had a peak population of approximately 6,000 individuals in 2008. Like the other hypoxia sensitive species, the coral population shrank as a result of the 2016 event. While the shrimp populations recovered by 2018, the coral population continued to decline to approximately 1% of their peak population size, with only 66 individuals observed that year (Figure 2). The 2016 event also introduced a new coral predator to the system. The striped nudibranch *Armina californica* had never been observed in the community before 2016, but a small population has since established itself and fed on the remaining corals in the most recent ROV surveys. The community has yet to recover fully because the coral population remains small, with only 77 individuals observed in the most recent ROV survey performed in 2020. If we exclude the effect of future extreme events, the coral population's recovery to historic numbers will likely take decades, if not centuries, given their low recruitment potential. (Chu et al. 2020).

The story in Saanich Inlet likely reflects what can occur throughout the northeast Pacific Ocean during an extreme climate stressor event. Saanich Inlet's featured species are found throughout the Salish Sea and have distributions throughout the northeast Pacific Ocean. Maintaining these time-series have been challenging but has been made possible through collaboration with Ocean Networks Canada, Fisheries and Oceans Canada, and the University of Victoria. Long-term biodiversity time-series are invaluable to understanding the current state of our rapidly changing oceans, and such data are exceedingly scarce in the deep-sea. This tireless effort has shown that continuous ecological monitoring is needed to establish the empirical connections between climate change and the vulnerability of species to extreme stressor events when they are exposed to conditions that exceed the norm.

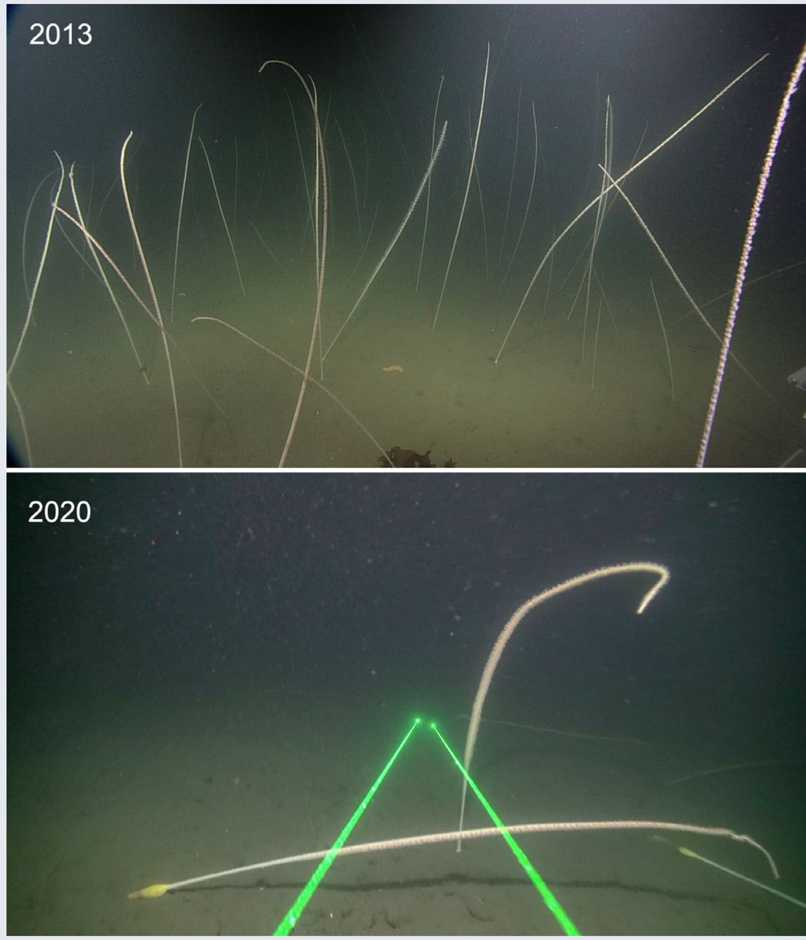

Figure 2. The density of the Halipteris willeomsi coral population before and after the 2016 severe hypoxia event in Saanich Inlet, British Columbia, Canada. Lasers are spaced approximately 10 cm apart in the lower panel.