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15

EELGRASS VARIATIONS TIES TO SEA LEVEL VARIATIONS

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In the summer of 1991, out of curiosity and to train interns in measuring the fundamental ecological process of primary production, we started measuring the growth rate of eelgrass (*Zostera marina*) every two weeks in a lush meadow near our lab at the mouth of Sequim Bay. In all but two summers since then, with the help of student interns and volunteers, we have continued to measure the growth rate between May and August. After about ten years, we started to look at the data. Although visually we did not see obvious differences in the meadow, we found that the growth rates varied substantially between summers. We wondered why.

In an effort to explain the results, we first organized the knowledge on the factors that affect eelgrass. It is well established that eelgrass is found at the dynamic interface between the lower intertidal and the shallow subtidal zones where suitable conditions of the sediment, wave energy, salinity, temperature, and light occur. The fact that eelgrass does not like to dry out (desiccate) limits its upper extent in the intertidal zone. Because it needs light to live and grow, and because light decreases in water with depth as well as turbidity, the lower depth it can exist at is a function of the amount of light reaching the bottom. So that explains the broad range of distribution, but does it help explain why eelgrass grew faster some years than others in our study plot? We enhanced our monitoring of growth by including light and temperature measurements, and collected data throughout Puget Sound on depth distribution of eelgrass. We also examined the data developed by the Washington State Department of Natural Resources eelgrass monitoring program, which began in the early 2000s and engaged eelgrass experts in discussions about our question.

During the 1990s, the issue of sea level rise (SLR) driven by global warming began to be studied more closely. We had an early interest in the effect of SLR on tidal marshes and studied accretion rates of marshes in our region in 1991. Sea level obviously could affect eelgrass also. The SLR scenarios under investigation were largely steady increases in sea level, with nuances associated with local conditions such as land subsidence and isostatic rebound. Based on the studies by the Washington State Department of Ecology and others, it turned out that the relative SLR rate on the shoreline in the Sequim Bay area was close to zero; there was no effect on eelgrass based on this scenario. However, while exploring the sea level variation tracked by NOAA, we noticed that the tide level recorded by sensors in Port Angeles and Port Townsend varied from the tide level predicted by tide models on many days. Short-term variations appeared to be caused by localized storm events pushing water levels higher via storm surge. We also noticed that longer-term (i.e., weeks to months) differences in mean sea level were occurring. We termed these longer-term variations mean sea level anomalies.

Several conditions can cause anomalies in mean sea level, among them being local storms and El Nino and La Nina events. El Nino events result in heating and thermal expansion of the North Pacific Ocean. The Oceanic Nino Index (ONI) is basically the temperature of the surface water in a region near the equator compared with the long-term mean. An ONI between -0.5 and +0.5 indicates a neutral ONI. Values of the ONI above and below that range indicate El Nino and La Nina conditions, respectively. The monthly mean sea level anomalies recorded near Sequim Bay between 1990 and 2013 ranged from -0.16 to +0.38 meters—a total range of 0.54 meters or almost 2 feet.

This longer-term variation could influence eelgrass growth by sustained periods of either low water levels or high water levels. Knowing the factors that control eelgrass growth, higher tides could enhance growth of the plants at our intertidal site by reducing the period of drying during summer, whereas extended lower tides could slow growth via greater desiccation. Plotting the growth rates over a period of 1991 to 2013 against mean sea level and the ONI showed a reasonably consistent pattern, with higher growth rates during periods of higher mean sea level, especially during El Niños and vice versa with La Ninas. Also, plotting growth rates against desiccation stress (measured in percent of daytime hours the plants were emerged) as well as the mean maximum temperature showed strong negative correlations with growth.

So we think we have at least part of a plausible explanation for the variation in growth rate. We examined old long-term data on eelgrass shoot density from Willapa Bay and near the Clinton Ferry Terminal on Whidbey Island and found that the variation seen there could be at least partially explained by sea level and/or temperature variations. In a study of Padilla Bay, Kairis and Rybczyk (2010) found that the steady increase in sea level would result in an increase in eelgrass area. This is because as the sea rises, the area above the current limit of eelgrass would be subjected to less desiccation stress and should be suitable for eelgrass. At the lower depth distribution of eelgrass, the typically clear water should allow eelgrass to persist (not decline), at least until depths and/or turbidity increase substantially.

The portion of the eelgrass meadow where our long-term growth studies were conducted inexplicably started to become less dense in 2014 and finally disappeared in 2016. This collapse of approximately 700m^2 corresponded with the anomalous warm water conditions termed the Blob. Although we are still trying to figure out the mechanism for this collapse, our observations indicated that Canada geese had started to congregate during this period in numbers we had never seen before. They tended to congregate in the area of our sampling plot, where they were observed eating eelgrass. Unlike Brant geese that only eat the leaves, Canada geese pull up the leaves and the rhizome. Importantly, eelgrass regenerates its shoots from the rhizome, and with that gone, the eelgrass cannot quickly recover. We are not sure if the geese were the primary cause of the collapse or why they suddenly started to show up on the site, but they surely contributed to it.

Although the collapse necessitated that we relocate our monitoring plot, perhaps one of the things we learned that can be applicable elsewhere is the advantage of monitoring something for a long time (28 years so far) in the same place as where factors influencing variation can be studied. We had the advantage of using a site located within 150 meters of the laboratory to conduct these studies. It has allowed us to tease out causal factors causing eelgrass variation and collapse, and to link these to events occurring hundreds to thousands of miles from the site. Coupling these local long-term findings with research and monitoring done in Salish Sea and globally will help us better understand the longer-term effects of global warming and perhaps other human and natural-derived pressures on coastal ecosystems, and provide clues on how to make these system more resilient to these pressures.