Growth dynamics of giant kelp studied using novel remote sensing data

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Giant kelp canopy showing fronds with varying physiological condition. Lighter colored senescent fronds contain less chlorophyll pigment and are generally older than darker frond with higher chlorophyll content. Credit: Tom Bell, Woods Hole Oceanographic Institution

The macroalga giant kelp, which is an iconic and important ecosystem-

structuring species found off the coast of California and many other coastlines, can grow 100-feet long within 1–2 years.

Now, researchers using novel remote sensing observations have found that different factors may bear on the spatial growth dynamics of the Macrocystis pyrifera kelp, which is the largest species of algae in the world.

Researchers studying the giant kelp in the Santa Barbara Channel off the coast of California, have found that "spatiotemporal patterns of physiological condition, and thus growth and production, are regulated by different processes depending on the scale of observation," according to the report 'Nutrient availability and senescence spatially structure the dynamics of a foundation species,' published in the *Proceedings of the National Academy of Sciences* (*PNAS*).

"Depending on your spatial scale of observation—whether you are looking at kelp forests regionally or really honing in on a specific local area—the patterns that manifest at these scales may be indicative of different drivers," said lead author Tom Bell, assistant scientist in the Woods Hole Oceanographic Institution's Department of Applied Ocean Physics & Engineering.

"On a regional scale for areas larger than one kilometer, seawater nutrients were related to the physiological condition dynamics of kelp. However, on local scales of less than one-kilometer, internal senescence processes related to kelp canopy age demographics were related to the patterns of biomass loss across individual kelp forests, despite uniform nutrient conditions," said Bell. Senescence is the progressive and irreversible deterioration in an organism's physiological performance.

The researchers focused on a 4,000 square kilometer study area in the Santa Barbara Channel off the coast of California.

Bell has studied giant kelp firsthand, scuba diving through the kelp forests. He says that the kelp, which is anchored at the sea floor, looks like tree trunks with bundles of translucent kelp fronds that form a canopy at the water's surface.

However, because field measurements of kelp occur over small scales, researchers teased out the roles of the external environment and internal biotic drivers on kelp population dynamics by combining longitudinal field observations with remote sensing observations.

The researchers used remote sensing data from several sources. Sea surface temperature dynamics in the channel were assessed using 4-kilometer resolution Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua satellite sensor products. Landsat 5, 7, and 8 satellite imagery of giant kelp allowed researchers to track kelp canopy biomass and age dynamics. Each Landsat image swath is 185 kilometers wide, and images have a pixel resolution of 30 meters.

In addition, the researchers incorporated into their studies novel 11-kilometer-wide repeat hyperspectral image swaths of the Santa Barbara Channel taken by the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) sensor, which has a pixel resolution of 18 meters. The optical sensor, which provided calibrated images of the spectral reflectance in the channel, flew on high-altitude airplanes as part of NASA's Hyperspectral Infrared Imager (HyspIRI) Preparatory Airborne Campaign. HyspIRI is a preparatory mission for NASA's planned Surface Biology and Geology satellite mission, which could launch later this decade.

The researchers used this hyperspectral imagery to examine the spatial patterns of the kelp canopy chlorophyll to carbon ratio, an established proxy for physiological condition, which is positively associated with kelp growth rate, frond initiation, and biomass accumulation. They

found that the physiological condition of the kelp canopy declined predictably with age and that older sections of the kelp forest with low physiological condition were more likely to be lost in subsequent months.

Bell said that through this research, he is also trying to help show some of the capabilities for the upcoming satellite mission.

"In the near future, scientists are going to have the opportunity to use hyperspectral data globally, and this will give ecologists another tool in their toolkit to understand how systems change, whether those systems are lowland tropical forests or giant kelp," he said. "This is going to be more important than ever as the environment becomes less predictable. It seems like the more data we have, the more we realize that we cannot predict ecosystem dynamics based on past observations because the climate is changing so rapidly. The availability of direct assessments of plant health from these new sensors will help scientists monitor ecosystem state and anticipate change."

More information: Tom W. Bell et al, Nutrient availability and senescence spatially structure the dynamics of a foundation species, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2105135118

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