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[Sonia Fernandez](#)

Disturbance has a greater effect on giant kelp productivity than does resource availability

Marine scientists at UC Santa Barbara have found that disturbances to giant kelp forests have a major influence on their net primary productivity (NPP) — an indicator of an ecosystem’s health and its ability to support its community — even more so than the availability of the resources it needs to grow. Taking data from decades of monthly measurements in the kelp forests of the campus’s National Science Foundation-supported Santa Barbara Coastal Long Term Ecological Research (SBC LTER) site, the researchers uncovered the direct, indirect and fascinating effects of disturbance on one of the world’s most productive ecosystems.

“We found that giant kelp productivity is controlled less by how fast kelp grows and more by how much kelp survives disturbance,” said graduate student researcher Billie Beckley, the lead author of a paper [published in the journal Ecology](#). The findings, from research sponsored by NSF, highlight the understudied role of disturbance in controlling ecosystem productivity, and may provide insight for conservation and restoration in ecosystems that are experiencing increased disturbance due to changes in land use and climate.

A disturbance-driven ecosystem

One of the defining features of giant kelp forests is their transience. Unlike many terrestrial ecosystems, which may undergo large scale disturbances on cycles of decades or more, giant kelp stands experience biomass-removing forces frequently throughout the year. Waves and storms pummel these fast-growing algae, often sending their fronds and spores elsewhere in the nearshore environment to establish other kelp stands anew, or to the shore as wrack to nourish nearby beach food webs.

Marine Science Institute senior researcher and co-author Daniel Reed noted the importance of disturbance-driven fluctuations on giant kelp productivity in a 2008 paper that analyzed four years of data collected from kelp forests surveyed by the SBC LTER. The analysis led to a conceptual model of the factors controlling year-to-year variation in kelp productivity. However, a deeper understanding of kelp ecology comes with long term monitoring, one that allows researchers to observe trends in the life cycle of the kelp in a variety of conditions, Reed said. Since the 2008 paper, giant kelp surveyed by the LTER have undergone a major heat wave, an explosion of purple sea urchins, and episodic burial of reef substrate from shifting sands — all of which have threatened their existence and that of the many animals that rely on them.

“Kelp forests in particular are touted as being one of the most productive ecosystems in the world, yet there really were no time series or datasets on primary production,” he said. “You need a high frequency of sampling in these systems because the kelp turns over so quickly.”

The seaweed grows so fast, Reed explained, and there’s such a high rate of turnover that monthly sampling is required to document the amount of biomass that is lost with disturbance events, which include not just storm and wave action but also factors such as anomalies in water temperature or predation by sea urchins. This variation is often masked by the seaweed’s rapid growth.

Armed with 16 more years of monthly data, the researchers were able to test the conceptual model they developed in 2008 across a wide range of environmental conditions to build a more deeply nuanced understanding of Southern California’s kelp forests and how interannual disturbance affects their net primary production. They looked at the three main aspects of NPP in kelp: initial production potential, or how much kelp biomass exists at the start of the growing season (late winter/early spring); recruitment of new plants, or how successfully kelp spores settle a given

area; and kelp growth.

“Winter storms strongly shape how productive kelp forests are by removing biomass and changing the forest’s ability to recover,” Beckley said. Indeed, in their evaluation of the data in their 20-year time series, the researchers attribute the majority of kelp NPP variability to how well they survive winter storms, combined with the ability of new plants to establish themselves.

This stands in contrast to typical terrestrial ecosystems, in which the foundation species are more strongly influenced by resource availability. “What typically drives year-to-year variation in productivity in terrestrial systems are factors that affect the growth rate of plants such as temperature, water, nutrients and soil properties,” Reed explained. “We’ve had some of the warmest events on record with extended periods of very low nutrients, and despite these poor growing conditions, it was really still mechanical disturbance that seemed to drive the variability that we’re seeing.” The researchers were careful to point out that more intense and/or more frequent marine heatwaves could still have negative effects on the kelp forest’s NPP variability.

Their analyses also revealed indirect effects of disturbance on NPP variability and the fine balance that is struck between disturbance and growth conditions in the kelp forest.

“Winter storms strongly reduce productivity by removing biomass, but they can also indirectly promote productivity by creating space and allowing light to reach the new kelp recruits,” Beckley said.

Because giant kelp is a foundation species, the health of the kelp forests dictates the health of the diverse organisms that rely on them. But the effects go beyond the nearshore locations of these kelp stands, which is a major reason why it’s important to have a detailed picture of the role of disturbance on its productivity, especially at a time of climate-driven increases in storm intensity, such as the incoming El Niño event, predicted to become one of the strongest on record.

“It’s not just that kelp forests are an important ecosystem on our coast; it goes beyond that,” Reed said. “Most of the production that happens in the kelp forest doesn’t stay in the kelp forest — it gets exported both into deeper water and to the beach where it plays a formidable role in shaping nearshore food webs.”

Research in this paper was also conducted by Robert Miller at UCSB; Andrew Rassweiler at Florida State University; Max Castorani at the University of Virginia and Jarrett Byrnes at the University of Massachusetts Boston.

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Media Contact

Sonia Fernandez

Senior Science Writer

(805) 893-4765

sonia.fernandez@ucsb.edu

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