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In Search of Missing Nitrogen

Plants need nutrients to grow. No nutrients, no growth. So scientists were surprised to learn that giant kelp maintains its impressive growth rates year round, even in summer and early fall, when currents stop delivering nutrients. Clearly something else is nourishing the kelp, but what?

A team of scientists at UC Santa Barbara has made a breakthrough in identifying one of those sources. Their research suggests that the invertebrate residents of the kelp forests and reefs provide at least some of the nutrients the giant algae need in those sunny summer months. The findings appear in the journal Global Change Biology.

Giant kelp can grow up to 18 inches per day under ideal conditions. And sustaining these staggering growth rates requires a lot of nutrients, especially nitrogen. Upwelling brings nutrients from the deep sea to coastal ecosystems in Southern California, but this activity trails off each year beginning in May.

“There’s still nitrogen, but not enough to meet the demands of kelp,” said lead author Joey Peters, a doctoral student in the department of Ecology, Evolution, and Marine Biology. As a result, the region’s reefs and kelp forests face a potential shortage of nitrogen just as the long summer days are poised to fuel algal growth. However, previous studies by researchers at UC Santa Barbara’s Marine Science Institute (MSI) showed that kelp continues to grow during these seasons at similar rates. Clearly the algae have enough nitrogen; scientists simply needed to discover its source.

Peters and his co-authors, UC Santa Barbara professors Dan Reed and Deron Burkepile, saw the local community of sea-bottom invertebrates as a likely suspect. These invertebrates account for the majority of the animal biomass in the kelp forest's floor — up to 3 kilograms per square meter — and they're much more likely to stay put than other animals, meaning they reside in the same area consistently.

"The question was, do invertebrates supply enough nitrogen to meet the demands of kelp during the summer months?" Peters said.

To answer this, he measured how much nitrogen different invertebrates excrete through their waste. He collected animals, placed them in a container of filtered sea water, and then recorded the change in ammonium concentration after a given time — ammonium being the primary nitrogen compound in question. Peters looked at 14 species in total, including sea snails, limpets, lobsters and sea stars, which collectively account for around 90% of the invertebrate biomass on reefs in kelp forests off Santa Barbara.



Giant sea stars contributed the greatest amount of nitrogen to the ecosystem overall out of all the invertebrates the team looked at.

Photo Credit: NOAA

He found that invertebrates were in fact an important part of the nitrogen cycle of coastal ecosystems, especially lobsters and sea stars. That last bit came as quite a surprise, since those species account for only a small portion of the biomass in their community.

Sea stars are keystone predators, Peters explained, meaning their presence has an outsized effect in shaping the ecosystem. But it seems they're also keystone nutrient recyclers. The case is similar for lobsters, he added.

He thinks this may have something to do with their diets. Many invertebrates are herbivores, but lobsters and sea stars are predators. Their protein-rich diet produces more ammonium and other nitrogen-rich compounds in their waste.

Peters' results show that the waste from invertebrates is a consistent component of the mystery nitrogen, especially since these animals live on the reef year-round. He suspects most of these nutrients remain near the seafloor, rather than finding their way up into the water column and into the kelp forest canopy. Since kelp take in most of their nutrients at the canopy level, there must be more going on.

Peters plans to investigate what other groups of animals might contribute to the mystery nitrogen, especially higher up in the water column. He did, however, establish this as a source of nitrogen lower down in the kelp forest, where it can sustain understory algae, young kelp and phytoplankton.

A Regime Change

In 2013, an epidemic began wiping out sea star populations all along the West Coast. This sea star wasting disease was exacerbated in the following years by a warm water anomaly known as the Blob. Researchers saw a 99% decrease in the biomass of sea stars off the California coast, which brought nitrogen levels down by 80%, Peters said.

He was able to track this change thanks to nearly two decades' worth of data collected by the Santa Barbara Coastal Long Term Ecological Research Project (SBC LTER), a 19-year monitoring project run by MSI. It is part of a network of research projects funded by the National Science Foundation (NSF) to study long-term ecological phenomenon in a wide diversity of ecosystems. Researchers at the SBC

LTER make routine measurements of basic conditions in the ecosystem for use in myriad different studies.

This meant that, unlike in previous studies, Peters was able to take the nutrient dynamics he measured and project them on to 18 years of actual data on species biomass, rather than merely use a simulation. “This is so rare,” he said. “In most studies you just don’t get 18 years of context.”

The results are a testament to the importance of these long-term projects. “This study reveals how environmental change can affect subtle ecosystem dynamics in kelp forests,” said David Garrison, a program director in NSF’s Division of Ocean Sciences, which funded the research. “This work would only be possible at sites where long-term studies are underway.”



Sea stars were major sources of nitrogen in reefs in the Santa Barbara Channel before disease and rising temperatures devastate their populations. Since then, lobsters have emerged as the top nutrient recyclers.

Photo Credit: JOEY PETERS

Surprisingly, as sea star populations crashed, the number of spiny lobsters increased, and unlike sea stars, lobsters tend to congregate. The crustaceans hide away in dens during the day, which concentrates the nutrients from their waste. Peters wonders how the ecosystem will respond to this change.

In the summer of 2019 he plans to measure how these nutrient hotspots around lobster dens influence ecosystem dynamics. He’ll measure water chemistry, the growth rates of algae near the dens and changes in the seafloor community. He’s curious whether the nutrients will drive greater algal growth around the dens, which could lead to more herbivores moving into the area.

This study reflects a resurgence of interest in bottom-up ecology, namely, effects that trickle up from animals lower on the food chain to the ecosystem as a whole. In the past, ecologists focused almost exclusively on abiotic sources of nutrients. There was some talk about biotic sources in the 1980s, but there hadn’t been much published on the idea since, Peters explained. “However, during these periods of

nutrient limitation, there are missing sources of nitrogen feeding kelp growth," he said. "This study fills some of that hole."

Scientist still have more work to do in order to track down all the nitrogen, but these results have begun to unravel the mystery and take the investigation in a new direction. "It's not all about what animals eat," said Peters. "It's also about the nutrients they provide to the system. And the nutrients coming out of these animals turn out to be really important."

More research stories from the Santa Barbara Channel can be found in The Current's featured compilation, Channel for Discovery.

About UC Santa Barbara

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