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Deep Sea Corals Show Warmer Ocean Has Changed the Food Web

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Changes at the base of the food web in the North Pacific Subtropical Gyre, Earth's largest contiguous ecosystem, may be linked to warming and expansion of open ocean gyres

Long-lived deep-sea corals preserve evidence of a major shift in the open Pacific Ocean ecosystem since around 1850, according to a study by researchers at the University of California, Santa Cruz. The findings, published December 15 in Nature, indicate that changes at the base of the marine food web observed in recent decades in the North Pacific Subtropical Gyre may have begun more than 150 years ago at the end of the Little Ice Age.

Deep-sea corals are colonial organisms that can live for thousands of years, feeding on organic matter that rains down from the upper levels of the ocean. The corals' branching, tree-like skeletons are composed of a hard protein material that incorporates chemical signatures from their food

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sources. As a result, changes in the composition of the growth layers in deep-sea corals reflect changes in the organisms that lived in the surface waters at the time each layer formed.

“They’re like living sediment traps, recording long-term changes in the open ocean that we can’t see any other way,” said coauthor Matthew McCarthy, professor of ocean sciences at UC Santa Cruz.

Scientists can study sediment cores taken from the ocean floor for clues to past conditions in the oceans, but that approach is not very useful for the most recent millennia. In the open ocean of the North Pacific, sediment accumulates so slowly that the entire Holocene epoch (the past 12,000 years or so) is represented by less than 10 centimeters (4 inches) of sediment that has been stirred up by organisms living on the seafloor. “Even if there were good sediment records, we would never get the level of detail we can get from the corals,” McCarthy said.

To analyze the coral skeletons, the UCSC researchers combined carbon dating with a novel technique for analyzing nitrogen isotopes in proteins. They were able to reconstruct records over the past 1,000 years indicating that a shift occurred around 1850 in the source of nitrogen feeding the surface waters of the open ocean. **As a result of decreasing nitrogen inputs from subsurface water, the phytoplankton community at the base of the food web became increasingly dominated by nitrogen-fixing cyanobacteria, which are able to use the nitrogen gas absorbed by surface waters from the atmosphere.**

“In the marine environment, the two major sources of nitrogen are dissolved nitrate, which is more concentrated in the subsurface and deep water and is brought to the surface by upwelling, and nitrogen fixation by specialized microorganisms that are like the legumes of the sea,” explained first author Owen Sherwood, who worked on the study as a postdoctoral researcher at UCSC and is now at the University of Colorado, Boulder.

The shift revealed in the coral record–from an ecosystem supported by nitrate coming up from deeper waters to one supported more by nitrogen-fixing organisms–may be a result of the North Pacific Subtropical Gyre expanding and becoming warmer, with more stable layering of warm surface water over cooler subsurface water. This increased “stratification” limits the amount of nutrients delivered to the surface in nutrient-rich subsurface water.

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Scientists have observed warming and expansion of the major mid-ocean subtropical gyres in the past few decades and have attributed this trend to global warming. The new study puts these observations in the context of a longer-term trend. “It seems that the change in nitrogen sources, and therefore possibly large-scale shifts in ocean conditions, switched on at the end of the Little Ice Age and it is still continuing today,” McCarthy said.

A key innovation in nitrogen isotope analysis was crucial to this study. Nitrogen-15 is a minor stable isotope of nitrogen, and the ratio of nitrogen-15 to nitrogen-14 is widely used to trace different sources of nitrogen. The nitrogen fixed by cyanobacteria in surface water, for example, has a different isotope ratio from the nitrates in deep ocean water. The isotope ratio also changes as organisms eat each other and nitrogen moves through the food web, with organisms at the base of the web having lower ratios than organisms at higher “trophic levels.”

Thus, two independent factors–the trophic level and the original source of the nitrogen–determine the nitrogen isotope ratio in an organism. McCarthy’s lab developed a technique that can separate these two factors by analyzing individual amino acids–the building blocks of proteins. It turns out that the isotope ratios of some amino acids remain unchanged as they move up the food web, while other amino acids become enriched in nitrogen-15 with each trophic transfer.

“Amino acid analysis decouples the two effects so we can see their relative magnitudes,” McCarthy said. “What we’re seeing in the central Pacific is a major shift at the base of the food web.”

The extent of the change is dramatic: a 17 to 27 percent increase in nitrogen-fixation since about 1850, after almost a millennium of relatively minor fluctuations. “In comparison to other transitions in the paleoceanographic record, it’s gigantic,” Sherwood said. “It’s comparable to the change observed at the transition between the Pleistocene and Holocene Epochs, except that it happens an order of magnitude faster.”

These and other recent results are changing scientists’ notions about the stability of open ocean gyres such as the North Pacific Subtropical Gyre, which is the largest contiguous ecosystem on the planet. These open ocean gyres were once considered relatively static, nutrient-deprived “deserts.” In the 1980s, however, scientists began regularly monitoring oceanographic conditions at deep-water station ALOHA near Hawaii, revealing a surprising amount of variability.

"Instead of relatively constant ocean deserts, time-series data has shown dynamic decadal-scale changes," McCarthy said. "Our new records from deep-sea corals now show that the decadal-scale changes are really only small oscillations superimposed on a dramatic long-term shift at the base of the Pacific ecosystem. This long-term perspective may help us better predict the effects of global warming on open ocean regions."

The new findings also suggest a new interpretation of data from other researchers showing changes in nitrogen isotopes in the bones of seabirds. A recent study of Hawaiian petrel bones using bulk nitrogen isotope data attributed the change to shifts in the length of open ocean food chains, possibly induced by overfishing (forcing petrels to feed lower on the food chain). In fact, the compound-specific data strongly imply that isotopic changes on all trophic levels are more likely due to the long-term shift in nitrogen sources at the base of the food web, McCarthy said.

Coauthor Tom Guilderson, who is affiliated with UCSC and Lawrence Livermore National Laboratory, has been collecting deep-sea corals for more than a decade to study them for clues to past oceanographic and environmental conditions. He teamed up with McCarthy to initiate this project. In addition to McCarthy, Guilderson, and Sherwood, the coauthors of the paper include UCSC graduate students Fabian Batista and John Schiff.

Coral samples were collected by the Hawaiian Undersea Research Lab's Pisces V submersible, with funding from the National Oceanic and Atmospheric Administration (NOAA) and the National Geographic Society. The bulk of this research was funded by the National Science Foundation.

- See more at: http://theterramarproject.org/thedailycatch/deep-sea-corals-show-warmer-ocean-has-changed-the-food-web/?goback=%2Egde_3667510_member_5819465590754004992#%21

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