Sea Slugs as Brilliant Indicators of Climate Change in Central California

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SUMMARY

This project examines whether rocky intertidal nudibranchs (brightly colored shallow-water mollusks also known as sea slugs) can be used as fine-scale indicators of inter-annual and decadal-scale climate variability. As part of this research, biologists offer a partial explanation for an observed decline in sea slugs off Central California, and document the climate-induced range shift of one particularly aggressive predatory "killer" sea slug and its effect on intertidal ecology at Duxbury Reef in Marin County. Field studies have led to the discovery of two new species of sea slugs.

A newly discovered species of nudibranch (*Flabellina goddardi*) lays its doily-like egg mass. Image: J. Goddard/UCSB

The voracious sea slug *Phidiana hiltoni* has decimated local sea slug populations in Marin County. Image: G. McDonald/UCSC

PROJECT

Biologists conducted quarterly surveys of intertidal sea slug populations at Duxbury Reef in Marin County, Pillar Point in San Mateo County, Scott Creek in Santa Cruz County, and Asilomar in Monterey County for a three-year period beginning in 2007. The sampling was designed to dovetail with historical studies of the same sites.

The nudibranch data were analyzed in relation to six indices of ocean climate: (i) multivariate El Niño-Southern Oscillation; (ii) Pacific Decadal Oscillation (PDO); (iii) sea surface height (SSH) at San Francisco; (iv) sea surface temperature (SST) off Monterey; (v) North Pacific Gyre Oscillation (NPGO); and (vi) coastal upwelling near Monterey. The resulting correlations were then analyzed, in a method the scientists call "climate-index response profiling," to examine "climate drivers of population change."

FINDINGS

Total nudibranch abundance was highly correlated with warming (i.e., El Niño events, elevated SSH and SST and the warm phase of the PDO). It was negatively correlated with La Niña events, the cold phase of the PDO, enhanced coastal upwelling and the "positive" phase of the NPGO.

Overall, nudibranch numbers at the four survey sites roughly doubled during El Niño events, as compared to La Niña events, and rose as much as 100-fold when El Niño episodes occurred during warm phases of the PDO and negative phases of the NPGO. Observed declines in sea slug abundances in the last decade are attributed to colder-than-normal La Niña-like conditions in Central California during this time.

Analyses suggest that different climatic modes affect nudibranch recruitment success by changing patterns of larval advection, which may either transport larvae toward or away from the rocky intertidal zone.

Consistent with this, abundances of southern species declined during the 2008 La Niña – to levels comparable to those observed during the 1970s La Niña events; however, southern species did not increase in abundance during the 2010 El Niño, a relatively mild event, likely because of the positive phase of the NPGO, which is associated with enhanced southward flows off California and strong regional upwelling. Both impede northward advection of the larvae of southern species.

The biologists documented a northward range shift (since 1977) of the large aeolid, Phidiana hiltoni, to Duxbury Reef and a corresponding decline in the abundance of other nudibranchs there. This species appears to have caused these declines through a combination of direct predation and competition for hydroid prey.

During related field surveys, biologists discovered two new species, one of which has since been named Flabellina goddardi.

APPLICATIONS

In terms of the project's application to management, nudibranchs potentially could be used to detect and monitor fine-scale climate change along the coast and to forecast ups and downs in the populations of other species with long pelagic larval periods, notably the commercially important red sea urchin. The larger, more conspicuous nudibranch species would be appropriate for monitoring by biologists and citizen scientists, especially in marine protected areas.

Sea slugs feeding. Image: J. Goddard/UCSB

P. hiltoni feeds on a hydroid. Image: B. Green

OUTREACH

The California Academy of Sciences in San Francisco produced a "science in action" video based on the results of this work. In addition, 17 community volunteers were trained to help gather survey data for the project. Research results were featured by public radio and National Geographic news.

PUBLICATIONS

Goddard J.H.R., Gosliner T.M., and Pearse J.S. (2011) Impacts associated with the recent range shift of the aeolid nudibranch Phidiana hiltoni (Mollusca: Opisthobranchia) in California. Marine Biology, DOI:10.1007/s00227-011-1633-7.

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This publication is based on research project R/OPCENV–08, funded by the Ocean Protection Council (OPC), and is supported by NOAA Sea Grant, U.S. Department of Commerce, under grant NA10OAR4170060, project C/P-1. The views expressed herein are those of the authors and do not necessarily reflect the views of NOAA or any of its sub-agencies. The U.S. government is authorized to reproduce and distribute for governmental purposes. This document is available in PDF on the California Sea Grant website: csgc.ucsd.edu. California Sea Grant, Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, Dept. 0232, La Jolla, CA 92093-0232 Communications Phone: 858-534-4446