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## Predictions of Climate Impacts on Fisheries Can be a Mirage

**New mathematical tool developed by a Scripps scientist can help avoid misleading conclusions for species management**

In the early 1940s, California fishermen hauled in a historic bounty of sardine at a time that set the backdrop for John Steinbeck's "Cannery Row" novel. But by the end of the decade the nets came up empty and the fishery collapsed. Where did they all go? According to a new study led by scientists at Scripps Institution of Oceanography at UC San Diego, the forces behind the sardine mystery are a dynamic and interconnected moving target.



*of climate impacts on sardines can be misleading.*

Publishing in the *Proceedings of the National Academy of Sciences*, Scripps graduate student Ethan Deyle, professor George Sugihara, and their colleagues argue that problems lie in seeking answers one factor at a time, as scientists have done for decades. What is the impact of climate on sardines? What is the effect of overfishing on sardines? Focusing on single variables in isolation can lead to misguided conclusions, the researchers say.

“Studying ecosystems in this piecemeal way makes it hard to find quantitative relationships, the kind that are useful for management and stand the test of time,” said Deyle.

Instead, using novel mathematical methods developed last year at Scripps, the researchers argue that climate, human actions, and ecosystem fluctuations combine to influence sardine and other species populations, and therefore such factors should not be evaluated independently.

The technique developed by Sugihara and his colleagues, called “convergent cross mapping,” takes multiple variables into account and avoids the centuries-old “correlation does not imply causation” issue that has plagued single-factor studies (see: <http://scrippsnews.ucsd.edu/Releases/?releaseID=1292>). For example, based on data

from the Scripps Institution of Oceanography Pier, studies in the 1990s showed that higher temperatures are beneficial for sardine production. By 2010 new studies proved that the temperature correlation was instead a misleading, or “mirage,” determination.

“Mirages are associations among variables that spontaneously come and go or even switch sign, positive or negative,” said Sugihara. “Ecosystems are particularly perverse on this issue. The problem is that this kind of system is prone to producing mirages and conceptual sand traps, continually causing us to rethink relationships we thought we understood.”

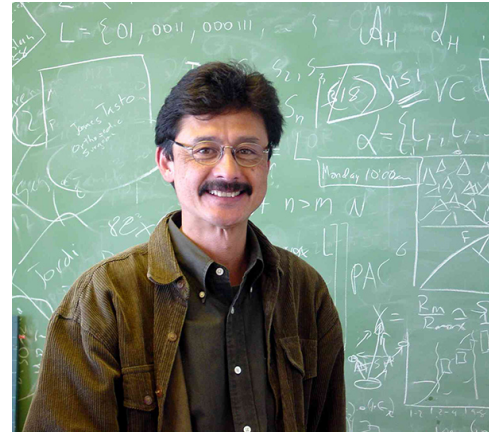
By contrast, convergent cross mapping avoids the mirage issue by seeking evidence from dynamic linkages between factors, rather than one-to-one statistical correlations.

“Sustainable sardine fishing based on ecosystem-based management should adapt to dynamic changes in the ocean environment, and future policies should incorporate these effects to avoid another ‘cannery row,’” said Deyle.

The investigation into the cause of the 1940s sardine collapse spawned the launch of the California Cooperative Oceanic Fisheries Investigations (CalCOFI), one of the world’s longest and most valuable marine research programs that continues today with support from Scripps, NOAA’s National Marine Fisheries Service (Southwest Fisheries Science Center), and the California Department of Fish and Game.

In addition to Deyle and Sugihara, coauthors of the paper include Michael Fogarty of the National Marine Fisheries Service, Northeast Fisheries Science Center; Chih-hao Hsieh of National Taiwan University; Les Kaufman of Boston University; Alec MacCall and Stephan Munch of the National Marine Fisheries Service, Southwest Fisheries Science Center; and Charles Perretti and Hao Ye of Scripps.

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