06-17

Project Title: I. Building a Framework For Fisheries Forecasting: Understanding Nonlinear Couplings between Fishing, Climate Change and Variability in Fish Populations.
II. A Retrospective Analysis of Nonlinear Forecast Methods for Fisheries Ecosystems.

Principal Investigators and Students: George Sugihara, Roger Hewitt, Chih-Hao Hsieh, Christian Anderson

Goals:

1) Understanding the sources of variability in marine fish populations (separating anthropogenic effects from natural causes).

2) Investigate the applicability of modern time series forecasting methods, and develop new methods for extracting information from time series data.

3) Establish baseline information for predictive models of the CCE. And other fisheries of opportunity (for which appropriate data are available).

Approach:

1) The project objective of understanding sources of variability (both anthropogenic and environmental) is addressed by using historical icthyoplankton data for the southern CALCOFI domain. These unique data were used to answer a classic question in marine fishery management: whether fishing itself will increase or dampen the population variability of targeted fish species.
2) The project objective using nonlinear methods to improve stock ***prediction*** directly addresses the overall NOAA Fisheries mission. It is essential information for setting harvest targets of fished species in the CALCOFI domain.
3) Demonstrating the applicability of the forecasting technology and refining the methods to apply specifically to data of this kind produces base-line information required to build predictive models for the CCE. How much predictability is there and how complicated do the models need to be? Additionally, the nonlinear methods developed here can identify what the coupled ecological subsystems (e.g, communities) are, for the larger national mission of ***ecosystem-based management***.

Work Completed:

We have obtained the following results:

1) Found fishing increases boom and bust variability of exploited populations. This is a classical question in fisheries science that we were able to answer generally and empirically for the first time. (Mentioned by VAdm Lautenbacher at the National Academies of Sciences November 2006). The implication of this work is that the destabilization of the population is a consequence of common fisheries practices that target the larger older individuals. Thus it is significant to restore age-structure in rebuilding depleted stocks.
2) Confirmed that fishing results in a truncated age and size structure for the population, and further related this to destabilization of exploited populations.
3) Found nonlinear forecast methods are effective for fisheries. These methods work best when the time series composite is constrained by habitat type or region.

4) Found physical data for CCE are best described as linear stochastic (auto-correlated noise). They are high dimensional and effectively stochastic.
5) Found low dimensional nonlinearity in the population dynamics of both exploited and unexploited populations. Dimensionality is a fundamental constraint on the complexity of a model required to achieve a given level of predictability.

Applications:
Our results to date suggest that:

1) Time series forecasting methods should be deployed at very least as a supplement to existing stock assessment practices. They are shown to have significant forecast skill.

2) Fishery management policy and practices/technologies need to be developed to preserve age-size-structure of exploited populations. "Stop picking on the big guys" as the tabloids say.

Journal Articles: (all articles are in reviewed journals)

1) Anderson, C., C. Hsieh, S. Sandin, R.Hewitt, A. Hollowed, J. Beddington, R.M. May (2008) Why fishing increases variability of exploited stocks. **NATURE** (2008), April 17 issue.

2) Hseih, CH., C.S. Reiss, R.P. Hewitt and G. Sugihara (2008) Spatial analysis show fishing enhances the climatic sensitivity of marine fishes. **Canadian Journal of Fisheries**. April 17, 2008 issue.

3) May, R.M., S.A. Levin, and G. Sugihara (2008) Ecology for bankers. **NATURE** (2008) March issue.

4) Maye, A., CH. Hsieh, G. Sugihara, B. Brembs (2007). Order in spontaneous behavior in Drosophila. **PLOS**.

5) Hseih, CH., C. Anderson, G. Sugihara (2007) , Extending nonlinear analysis to short ecological time series. **American Naturist**. (December 2007 issue).

6) Hsieh CH, Reiss, C.S., Hunter, J.R., Beddington, J.R., May R.M., Sugihara G (2006) Fishing elevates variability in the abundance of exploited species. **NATURE**, 443, 859-862.

7) Southwood, T.R.E, R.M. May, G. Sugihara (2006) Some observations on related ecological exponents. **PNAS** USA: 2006;103;6931-6933.

8) Hsieh CH, Glaser SM, Lucas AJ, Sugihara G (2005) Distinguishing random environmental fluctuations from ecological catastrophes for the North Pacific Ocean. **NATURE** 435: 336-340.

9) Hsieh CH, C. Reiss, W. Watson, MJ. Allen, JR. Hunter, RN. Lea, RH. Rosenblatt, PE Smith, G. Sugihara (2005) A comparison of long-term trends and variability in populations of larvae of exploited and unexploited fishes in the Southern California region: A community approach. **Prog. Oceanography** 67:160-185.

Books/Articles-in-Books:

1) May, R.M, Crawley, Sugihara, 2007, Multispecies Patterns, in **Theoretical Ecology**

2) Sala, E. and G. Sugihara 2004. Food-web theory provides guidelines for marine conservation. In Aquatic Food Webs, ed. J. Cohen, pgs 170-183.

Reports:

1) **New Directions in Systemic Risk in The Financial Sector**, **(NAS Report in Press)** (Reviewed and produced by National Academy of Sciences Board on Mathematical Sciences and it's Applications, and the Federal Reserve Bank)

2) **SAP4.2 Writing team on "Critical Ecological Transitions and Environmental Change" (in progress).**

Conference Proceedings/Workshops:

1) Theoretical Ecology (Conference to honor Lord May, Oxford 2006)

2) 20 Years of Nonlinear Science in the Geosciences, (Workshop, Rhodes 2006).

3) Early Warning Signals of Critical Transitions (Workshop with Marten Scheffer et. al. 2007).

Distinguished Lecturer, Rutgers Institute of Marine Science (May 2008)

Ph.D. Dissertations:

Chih-Hao Hseih 2006.