Ecosystem Tipping Points the North Pacific: Identifying Thresholds in Response to Climate Change and Potential Management Strategies

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Introduction

We propose to hold a workshop in FY2015 that will bring together inter- disciplinary marine scientists to identify changing climate-driven thresholds that, when exceeded, may lead to tipping points in marine ecosystems of the North Pacific and the management actions that may be taken in response.

Tipping points[1] occur when small shifts in human pressures or environmental conditions bring about large, sometimes abrupt changes in a system—whether in a human society, a physical system, an ecosystem, or our planet's climate (Fig.1). An increasing number of examples of tipping points in ocean ecosystems around the world, ranging from reefs to estuaries to pelagic systems, are raising concern among scientists and policymakers. Changes in ocean climate, the abundance of key species, nutrients and other factors drive these shifts, with resulting effects on ocean food webs, habitats, and ecosystem functions that have direct impacts on people's livelihoods and well-being. Ocean tipping points may be cause for particular concern because they are hard to anticipate and can be very difficult, if not impossible, to reverse.

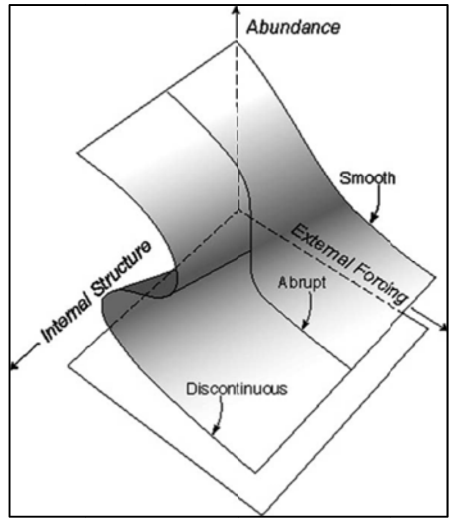

Figure 1. Illustration of how the ecological response to forcing can transition from a smooth response to an abrupt response to a discontinuous response. Abrupt and discontinuous responses represent tipping points. From Collie et al. (2004).

Tipping points can be characterized by having at least one of the following characteristics:

- There is a threshold beyond which an abrupt shift of ecological states occurs, such as a regime shift (e.g., Hare and Mantua, 2000; Scheffer and Carpenter, 2003; Steele 2004; etc.), although the threshold point can rarely be predicted with precision.
- The changes are long-lasting and hard to reverse, e.g., sardine-anchovy alternation (e.g., Schwartzlose et al. 1999; Collie et al. 2004).
- There is a significant time lag between the pressures driving the change and the appearance of impacts, creating great difficulties in ecological management (e.g., deYoung et al. 2008).

Tipping points are a major concern for decision-makers because of their potentially large impacts on biodiversity, ecosystem services, and human well-being. It can be extremely difficult for societies to adapt to rapid and potentially irreversible shifts in the functioning and character of an ecosystem on which they depend. The management challenges in crossing critical environmental thresholds associated with tipping points are further complicated by the impacts that potential local bifurcations and prolonged hysteresis can have on local and regional marine ecosystems. While it is almost certain that tipping points will occur in the future, the dynamics in most cases cannot yet be predicted with enough precision and advance warning to allow for specific and targeted approaches to avoid them, or to mitigate their impacts.

[1] Definition adapted from http://biodiversity.europa.eu/topics/tipping-points

Responsible risk management may therefore require a precautionary approach to human activities[2] known to modify ecosystem services.

Goals

There are five overarching goals to the proposed workshop that are focused on advancing the understanding of regional effects of climate change and ocean variability and vulnerability (e.g., ocean acidification, O_2 minimum zones, etc.) to minimize disruptive impacts, to guide adaptation choices to best manage future changes, and to inform sustainability strategies to ensure the continued benefits of healthy and productive marine ecosystems:

- Identify potential climate thresholds that may lead to ecosystem tipping points, consequences to the ecosystems once thresholds are crossed, and management actions in preparation for, or in response to, changes in ecosystem state.
- Identify potential leading indicators of ecosystem tipping points. Potential species include: sardine-anchovy regimes, shifts in composition of invertebrate populations (e.g., zooplankton, krill, gelatinous species, squid), and salmon returns.
- Identify potential mechanistic linkages between climate forcing, indicator species, and ecosystem tipping points. This will require selection of past extreme events as analogs of future change, as well as outlining the framework for the implementation of Climate and Earth System models to project ocean drivers and potential ecosystem response, and the needed coupled physical-biological models to identify mechanistic linkages.
- Highlight examples of how ecosystem tipping points can impact fisheries, fishery- dependent communities, and vulnerable species. Identify species in the region that may be most susceptible to ecosystem shifts.
- Identify opportunities to better apply and integrate climate tipping point data and information into fisheries stock assessments and management decisions.

Workshop deliverables

- Publication of a white paper that identifies key physical drivers, likely indicators of response to regional tipping points and management responses, and articulates the regional needs to advance the understanding and projection of the impacts of climate variability and change on fish or other species that support economically important fisheries,
- Initial scenario definition of ecosystem tipping points requiring model hindcasts, forecasts, and projections,
- Development of future science plans and working groups (e.g., within PICES) to continue statistical, modeling and socioeconomic efforts, and
- Identification of a suite of regional interdisciplinary research opportunities that will accelerate the development and transition of climate-marine ecosystem research findings and information to advance NOAA marine resource management.

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[2] Barnosky et al. (2012) discuss how the increase in human population is driving accelerated climate change through the increased use of fossil fuels, land modification, livestock biomass replacing predators, and agricultural nutrient loading. The burning of fossil fuels has increased atmospheric concentrations of CO_2 by ~35% from pre-industrial levels which has led to both increased atmosphere and ocean temperatures (greenhouse effect) and raising ocean acidity. Other impacts that may cause environmental thresholds to be exceeded include nutrient cycling in the coastal zones which has increased “dead zones,” ocean debris, and invasive species creating new tropic systems.