OSM Sessions on "*Ecosystem status, trends, and forecasts*" and "*Ecosystem resilience and vulnerability*"

by Thomas Therriault and Hiroaki Saito

Marine ecosystems are constantly changing. Therefore, researchers need to develop and to communicate information on ecosystem status, trends, and forecasts to ensure that sound management and policy decisions are made for the benefit of the societies that depend on them. Ecosystem indicators are one way to communicate such information, but the selection of the most appropriate indicators can prove challenging, especially given an increasingly complex array of audiences. It is likely that different indicators will be needed where the scale of ecosystem responses to different stressors must be reconciled with the scale of the perturbation (*e.g.*, coastal *versus* oceanic). Forecasting ecosystem change demands good understanding of how multiple stressors affect ecosystem structure and function. A key element of the FUTURE program is the ability to convey to diverse audiences, in each of the PICES member countries, ecosystem status, trends and forecasts. Session S4 on "*Ecosystem status, trends and forecasts*" explored current and proposed ecosystem status and trend indicators, including some already in use in the North Pacific Ecosystem Status Reports, and attempted to identify metrics required in support of ecosystem forecasts.

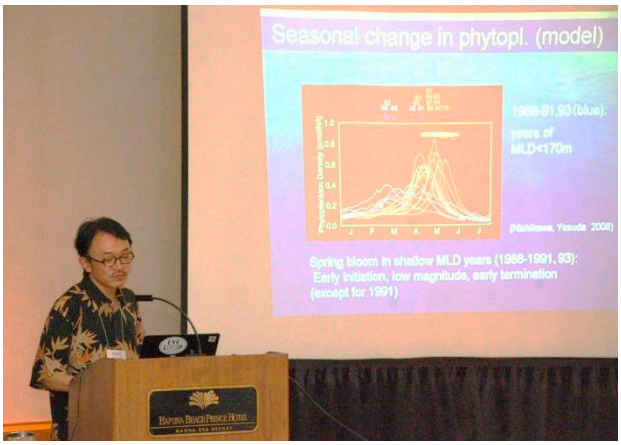
The plenary speaker, Dr. Deborah Steinberg, did an excellent job setting the stage for this topic session by giving a talk entitled "*Ecosystem comparison of trends in zooplankton community structure and role in biogeochemical cycling*". She presented an overview of the status of spatial variation in zooplankton biomass and implications for the biological pump that can be characterized by community structure. She then highlighted patterns of eutrophic and oligotrophic regions and provided links to climate indices or sea ice dynamics. With respect to trends, she used subtropical monitoring sites (BATS and HOT) to show that with increased warming, the biological pump is changing. Lastly, she argued the importance of understanding the mechanisms responsible for change as well as documenting changes in status and trend.

In the breakout session there were talks by Drs. Sanae Chiba and Sonia Batten that demonstrated how long-term zooplankton data sets could be analysed to find trends and patterns with respect to distribution. Dr. Chiba showed that the diversity index was correlated with the Kuroshio Extension Current strength (1960–1988), but that this relationship broke down during the oceanographic regime shift that followed this period. Dr. Batten explained how various indices obtained from Continuous Plankton Recorder (CPR) samples, such as the phytoplankton colour index, total diatom biomass, timing of the spring diatom bloom, warm-water copepod abundance, *etc*., could indicate ecosystem regime shifts. Talks by Drs. Douding Lu and Ichiro Imai assessed the trends and status of harmful algal blooms (HABs) by means of retrospective analysis of HAB data sets. Dr. Lu showed how increasing HAB events in Chinese coastal waters were related to increasing anthropogenic activity, such as eutrophication, ballast water, or aquaculture. Similarly, Dr. Imai demonstrated how new water quality regulations reduced eutrophication, improved water quality in the Seto Inland Sea, Japan, and decreased the number of HAB events. The session also had talks about status, trends, and forecasts for higher trophic levels. Dr. Jongjun Tian suggested an ecological indicator as an early warning signal for forecasting the future (current) regime shift. He was able to demonstrate how fish assemblage data were used to detect five past regime shifts (1911, 1934, 1963, 1975 and

S4 plenary speaker, Dr. Deborah Steinberg, addressing session participants on ecosystem cross-comparisons of zooplankton communities.

S4 speaker, Dr. Ichiro Imai, discussing long-term trends of red tides and toxic blooms in the Seto Inland Sea of Japan.

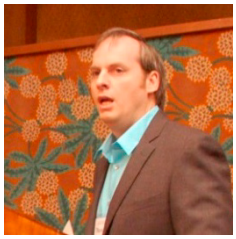
1988) and that these coincided with shifts in sea surface temperature and a climate index. Dr. Jon Brodziak used a striped marlin dataset to introduce participants to a new "steepness" index which can quantify population resilience, and be used to set biological reference points, such as maximum sustainable yield. Drs. Haruka Nishikawa and Suam Kim talked about ways to develop fishery forecasts for commercial target species (neon flying squid, Pacific flying squid) under global warming scenarios. Lastly, Dr. Hiroaki Saito's talk provided a nice summary of the session by considering mechanisms of fish species alternation in the western North Pacific which were induced by changes in the wind field in the central-eastern North Pacific. He pointed out the weaknesses of fisheries as a modern industry, *i.e.*, unplanned high variability, and that forecasting future changes in marine ecosystem and fisheries production is likely the most effective way to mitigate intrinsic weaknesses in modern fisheries. Clearly our understanding of the mechanisms creating observed ecosystem variation is still limited. Much remains to be done to "understand the mechanisms behind status and trends" and to "forecast future states", as these are essential science contributions to society.



Dr. Hiroaki Saito providing the final talk of Session S4.

S6 plenary speaker, Dr. Beth Fulton, chatting with Robin Brown during coffee break.

Marine ecosystems around the globe are affected by numerous natural and anthropogenic stressors. The interactions among stressors are incredibly complex and proving difficult to understand. Ultimately, these stressors will change ecosystem structure and function. This can lead to changes in ecosystem stability and productivity, and impact the societies that depend on them. One of the central themes of the FUTURE Science Plan focuses on ecosystem resiliency and vulnerability to natural and anthropogenic stressors and poses the question how ecosystems around the North Pacific might change in the future. Thus, the ability to understand how resilient marine ecosystems are and to characterize the degree to which ecosystems are vulnerable to change via multiple stressors is critical to advancing the FUTURE program. Session S6 on "*Ecosystem resilience and vulnerability*" attracted only a single submitted oral presentation, perhaps indicating the difficulty in quantifying resilience and vulnerability in marine systems with diverse stressors. Because of this problem, there has been little attention devoted to these issues to date in PICES. Dr. Beth Fulton explored resilience in a plenary talk titled "*Exactly how resilient are ecosystems?*".



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Dr. Hiroaki Saito (hsaito@aori.u-tokyo.ac.jp) is an Associate Professor at the Atmosphere and Ocean Research Institute, the University of Tokyo. He has a broad range of interests but his focus lies in the role of marine organisms in food-web dynamics and biogeochemical cycles. He is one of the establishing members of the A-line monitoring programme for the western North Pacific. He was a core member of the SEEDS I, II and SERIES Fe fertilization experiments, led the DEEP (2002 2007), SUPRFISH (2007–2012) projects, and is leading the SKED project (2011–2021). He has also been involved in IMBER, and was Chairman of IMBER-Japan from 2004–2008. In PICES, Hiroaki has been a member of several expert groups. He is currently a member of the BIO Committee and SG-SC-NP, is Chairman of the FUTURE AP-COVE, and is Vice-Chairman of Science Board.