ICES/PICES Symposium on "*Forage Fish Interactions*"

by Myron Pack, Tim Essington and Stefan Neuenfeldt

Fig. 1 The participants of the ICES-PICES symposium on "Forage Fish Interactions", November 12–14, 2012, at the Citées Congrès in Nantes, France.

Forage fish are small, often pelagic and schooling fishes that are a main pathway for energy to flow from plankton to higher predators in marine ecosystems. Because they maintain this trophodynamic role throughout their life, their population fluctuations may produce notable ecological effects and, therefore, the sustainable management of forage fisheries is critical to maintaining ecosystem functioning. A group of 70 scientists from 16 nations (Fig. 1) gathered near the banks of the Loire River in the city of Nantes, France, from November 12–14, 2012, for an ICES/PICES Symposium on "*Forage fish interactions: Creating the tools for ecosystem-based management of marine resources*". The symposium was organized around three overarching themes and questions:

- (Drivers of change) – How do environmental factors and predator-prey interactions drive the productivity and distribution of forage fish stocks across ecosystems world-wide?
- (Management of resources) – What are the economic and ecological costs and benefits of different forage fish management strategies? and
- (Common traits) – Do commonalities exist across ecosystems in terms of the effective management of forage fish exploitation?

The symposium was kicked off with a keynote address by Jake Rice (Canada), who provided a retrospective of important achievements in both field and modelling research that have paved the way towards our current view of forage fish as central players in the trophodynamic structure and function of marine ecosystems. The talk also highlighted how historical achievements have led to the development of the different strategies employed today to manage the exploitation of forage fish stocks. That keynote address set the stage for a series of oral and electronic poster (Fig. 2) presentations that were given within five theme sessions over the following three days.

Session 1 on "Climatic and biotic mechanisms and forage fish recruitment": Within this session, Akinori Takasuka (Japan) gave a keynote address that reviewed the various recruitment hypotheses that have been offered to explain world-wide, synchronous fluctuations in anchovy-sardine species pairs. Using different examples, he highlighted how subtle changes in mean growth rates and stage durations of early life stages may lead to dramatic consequences for survival and year-class success. Following that presentation, a number of talks illustrated how changes in the distribution and productivity of key forage fishes were associated with climate-driven changes in bottom-up processes (changes in physical forcing, zooplankton community dynamics, *etc.*). An emerging theme was the role of intra-guild predation and competition in population dynamics, particularly how intra-guild dynamics can amplify impacts of external drivers (*e.g.*, environment and fishing). Forage fish recruitment dynamics from a diverse array of habitats (from the Mediterranean and North Seas to the Seto Inland Sea of Japan) were discussed.

Session 2 on "Post recruitment predator-prey dynamics in ecosystems world-wide": In this theme session, Geir Huse (Norway) provided a keynote presentation that reviewed how swimming behaviour, which modifies the spatial overlap of forage fishes and their predators, has been utilized within biophysical food web models developed for the Barents and Norwegian Seas. The important tropho-dynamic role of forage fish as prey was highlighted in presentations that spanned a wide range of ecosystems (from sub-tropical seas to sub-Arctic habitats). Several talks emphasized the impacts that local changes in forage fish availability had to central-based predators such as marine mammals and seabirds. These presentations and discussions highlighted, in some cases, our lack of knowledge on the diet preferences and requirements of the predators of forage fish such as "charismatic mega-fauna" within complex food webs such as shelf sea ecosystems.

Fig. 2 Marisa Litz (USA) describes the electronic version of her poster on spatial and temporal influences of the Columbia River plume on the community structure of forage fish and other nekton over the Washington and Oregon shelf. Some of the onlookers include (from right to left) Myron Peck (Germany), Richard Nash (Norway), Maria Røjbek (Denmark), Geir Huse (Norway), Keith Farnsworth (UK), Ignacio Catalán (Spain), Lars Ravn-Jonsen (Denmark), Eckhard Bethke (Germany), Barbara Schoute (ICES) and (in profile) Georg Engelhard (UK).

Session 3 on "Linking biology and economics": An important element of the symposium was to bring together (and bridge any potential gaps between) biologists and economists. This represents a critical step towards advancing knowledge and tools useful in the management of forage (and other) fishes. The state of the art in coupling biology and economics was provided in a keynote address by Røgnvaldur Hanesson (Norway), who emphasized the need to more fully appreciate the economic role played by forage fishes. This includes estimates of their direct value not only in landings, but in associated industries and as products such as fish meal and forage. Forage fish also provide several ecosystem services (*e.g.*, supporting ecosystem and food web structure and maintaining healthy populations of other commercially exploited stocks) which are difficult to valuate but, nonetheless, need to be considered and compared when exploring the economic consequences of various management options.

Session 4 on "Ecosystem-based management": This session offered presentations that highlighted the role of forage fish within current ecosystem-based approaches to managing marine systems and included a keynote address by Jason Link (USA). Presentations stemmed from the recent Lenfest Forage Fish Task Force report, a comprehensive, global analysis of forage fish and their management. A reoccurring theme in many talks was that managing forage fish fisheries broadly hinges on striking a balance between utilizing different parts of the system and balancing biological and economic tradeoffs. These various management options must also be considered within the context of the large fluctuations in biomass typically observed in many forage fish stocks. It was discussed whether, in some cases, forage fish could be managed as one portfolio (as a single component). "How much forage fish should be left in the water for predators?" was a hotly contested question although it was clear from many talks that mortality due to predators is often (much) higher than the removal of forage fish due to fisheries.

Session 5 on "Direct comparisons between ecosystems and generic properties": This session explored whether commonalities existed among ecosystems and the role of forage fish in ecosystem structure and function. Jeremy Collie (USA) provided a keynote address that explored forage fish dynamics among various shelf sea ecosystems across the northern hemisphere. That presentation echoed the message within a variety of talks on the key role of forage fishes as planktivores and the common (and sometimes striking) community shifts that have been observed in the last decades as revealed in size-based ecosystem indicators (*e.g.*, mean ratio of "small" to "large" or "pelagic" to "demersal" species). Presentations explored and critically evaluated different approaches to model the effects of forage fish removals on food web dynamics. For example, generic, size-based (size spectrum) approaches are being used to explore how different harvest strategies of forage fish may impact upper and lower trophic levels and the contrasting responses of relatively "small" and "large" species to fishing mortality. A second presentation critically examined the design and performance of 18 existing ecosystem-based models in terms of their suitability to make projections regarding the potential consequences of changes in forage fish stocks on marine food webs.

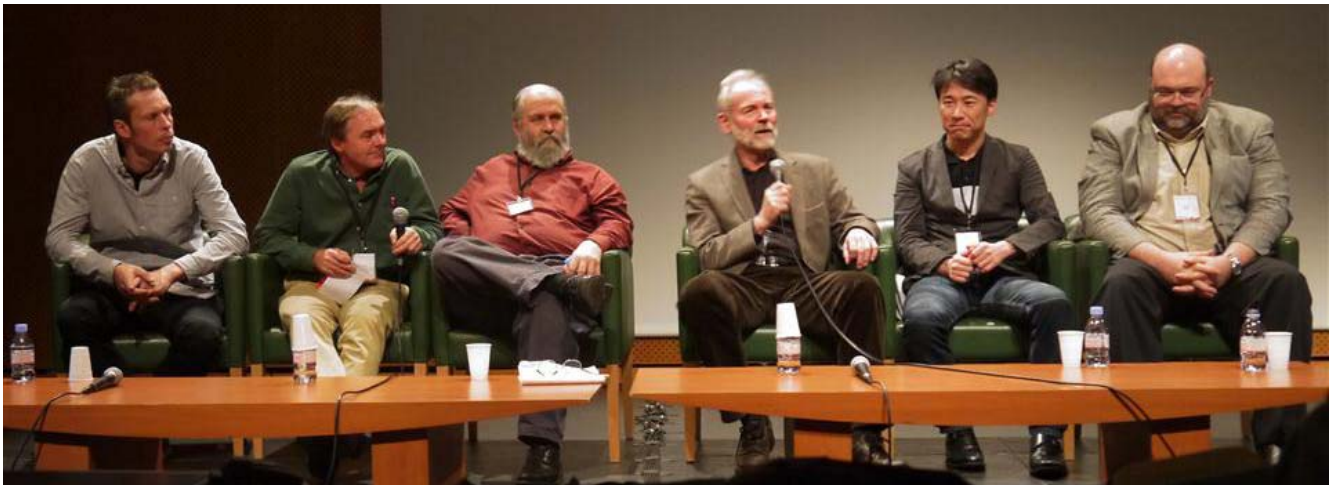

Fig. 3 The final event of the symposium was a panel discussion of keynote speakers which helped synthesize the take-home messages from the symposium. From left to right: Gier Huse (Norway), Jeremy Collie (USA), Jake Rice (Canada), Røgnvaldur Hanesson (Denmark), Akinori Takasuka (Japan) and Jason Link (USA).

The final event of the symposium was a Panel Discussion on "*What exactly is a healthy ecosystem? Managing forage fish: What do we want and why?"* The six keynote speakers (Fig. 3) fielded questions from the audience and offered their own opinions about remaining questions, the hot topics addressed in presentations, and future research needs concerning the effective management of forage fish within an ecosystem context. A special volume of the *ICES Journal of Marine Science* has been set to publish the results presented at this symposium.

The symposium was convened by Stefan Neuenfeldt (Denmark), Myron Peck (Germany), Tim Essington (USA), Niels Vestergaard (Denmark) and Vladimir Radchenko (Russia). A long list of people made the symposium run smoothly, including Olivier Berthéle, Mareike Volkenandt and Sophie Pilven. Special thanks are given to Verena Trenkel and Helle Sørensen who (similar to forage fish in many ecosystems) formed the essential "wasp-waist" by effectively channelling substantial amounts of local energy to the symposium's participants. Additional funding for the symposium was obtained from the EU project "FACTS".

Dr. Myron Peck (myron.peck@uni-hamburg.de) is an Associate Professor of Biological Oceanography at the University of Hamburg, Institute of Hydrobiology and Fisheries Science (Hamburg, Germany). He has a broad range of research interests related to physical and biological processes governing marine and estuarine species and food webs, including coupling species life history and physiology and translating that knowledge to models to advance predictive capacity.

Dr. Tim Essington (essing@uw.edu) is an Associate Professor of Aquatic and Fishers Sciences at the University of Washington (Seattle, Washington, USA). His research examines food web interactions within a wide range of marine, estuarine and freshwater habitats. A primary consideration is the structuring role played by fisheries and other anthropogenic effects. His research attempts to understand the potential conflicts between fisheries targeting species that occupy distinct positions in food webs.

Dr. Stefan Neuenfeldt (stn@aqua.dtu.dk) is a Senior Researcher at the Danish Technical University, Division of Aquatic Resources (DTU-Aqua) in Charlottenlund, Denmark. His research interests include multi-species interactions in marine systems, particularly predator-prey dynamics operating at different temporal and spatial scales. He also uses biotelemetry to explore various facets of fish behaviour. Stefan is the coordinator of the EU FACTS forage fish program.