Rebuilding depleted fish stocks: biology, ecology, social science, and management strategies

Cornelius Hammer, Olav Sigurd Kjesbu, Gordon H. Kruse, and Peter A. Shelton

Hammer, C., Kjesbu, O. S., Kruse, G. H., and Shelton, P. A. 2010. Rebuilding depleted fish stocks: biology, ecology, social science, and management strategies. – ICES Journal of Marine Science, 67: 1825–1829.

This is an introduction to an ICES/PICES symposium entitled as in the title of this manuscript. During the symposium, five theme sessions embraced the subject material under the headings “Impact of fisheries and environmental impacts on stock structure, reproductive potential, and recruitment dynamics”, “Trophic controls on stock recovery”, “Methods for analysing and modelling stock recovery”, “Social and economic aspects of fisheries management and governance”, and “Management and recovery strategies”. A panel discussion provided a valuable overview of current understanding and research focus.

Keywords: Fish stocks, ICES, PICES, rebuilding, recovery.

Advance access publication 13 May 2010.

C. Hammer: Institute for Baltic Sea Fisheries, Johann Heinrich von Thünen-Institute, Rostock, Germany. O. S. Kjesbu: Institute of Marine Research, PO Box 1870 Nordnes, N-5817 Bergen, Norway. G. H. Kruse: University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, Juneau Center, 17101 Point Lena Loop Road, Juneau, AK 99801, USA. P. A. Shelton: Department of Fisheries and Oceans, PO Box 5667 St John's, NL, Canada A1C 5X1. Correspondence to C. Hammer: tel: +49 381 8116-101; fax: +49 381 8116-199; e-mail: cornelius.hammer@vti.bund.de.

Introduction

The ICES/PICES/UNCOVER symposium on “Rebuilding depleted fish stocks: biology, ecology, social science, and management strategies” at Warnemünde, Germany, 3–6 November 2009, was initiated by the participants in the European Union (EU) UNCOVER project (understanding the mechanisms of stock recovery: contract no. 022717). Such an event was identified more than 5 years earlier as one of the final deliverables during the application for funding within the EU 6th Framework Programme (SSP-4-FISH Specific Targeted Research Project). The two leading objectives were (i) to present the most important results of the UNCOVER project to the broader scientific community and to the European Commission, and (ii) to amalgamate these results with other studies on the topic in a comprehensive and up-to-date volume documenting the successes and failures of stock-recovery plans worldwide.

The conference was hosted by the coordinator of the UNCOVER project, the Institute for Baltic Sea Fisheries (Rostock, Germany)—part of the Federal Johann Heinrich von Thünen Institute for Rural Areas, Forestry, and Fisheries—and took place in the “Yachthafenresidenz Hohe Düne” in Warnemünde on the Baltic Sea coast; an unusual place to convene a symposium that attracted participants from all over the world. Its timing coincided with the approaching end of the project, as well as a time of year—punctuated with the first snowfall of winter—when this venue was affordable for scientists. In addition to the EU, the International Council for the Exploration of the Sea (ICES) and the North Pacific Marine Science Organization (PICES), the symposium was generously co-sponsored by the host institute, the Department of Fisheries and Oceans (Canada), the Institute of Marine Research (Norway), the Northwest Atlantic Fisheries Organization (NAFO), and COST Action FRESH and the “Stiftung seeklar” (Germany). The 4-d symposium attracted ~150 scientists, managers, and national and international leaders of fishery organizations from a large number of countries around the Atlantic, as well as the Pacific Ocean.

Background

The UNCOVER project started early in 2006 and represented the largest fisheries project within the EU 6th Framework Programme with more than 120 scientific collaborators from more than 27 institutes in 14 participating countries. The entire project concentrated on four case-study areas in European waters and the major exploited predator and prey species inhabiting these areas: (i) cod, capelin, and herring in the Barents and Norwegian Seas; (ii) cod, herring, and plaice in the North Sea; (iii) cod and sprat in the central Baltic Sea; and (iv) northern and southern hake and anchovy in the Bay of Biscay (Figure 1). Its broader goals were to provide a thorough analysis of the state of these stocks taking into account recent changes in the respective ecosystems, as well as to provide clear-cut recommendations about how to rebuild those that were considered to be outside safe biological limits. More specifically, the prime objectives were to: (i) identify changes in attributes experienced during stock decline to better understand prospects of stock recovery; (ii) enhance the scientific understanding of generic mechanisms promoting or inhibiting stock recovery; and (iii) formulate recommendations to managers on implementing recovery plans that are likely to be effective. The intention was not to generate new data *per se*, but rather to integrate existing knowledge from published scientific studies and ongoing research projects and/or to carry out *de novo* research

Figure 1. UNCOVER partners and the four main case-study areas (drawn by C. Zimmermann, vTI-OSF).

on old data. Consequently, the recovery trajectories in relation to stock attributes observed in the case-study areas were to be put into the context of successes and failures of stocks to recover around the world.

Theme sessions

The symposium was structured around five topical theme sessions, preceded by a keynote address by Steven A. Murawski (USA), who underlined the timeliness of the symposium, because 25% of the world's fish stocks are currently overfished and require urgent management action. He concluded that the most successful recovery programmes are characterized by immediate, measurable, and drastic reductions in fishing mortality, instead of gradual, long-term reductions, but emphasized that a distinction should be made between "recovery" and "rebuilding"; the former referring to a straightforward increase in stock biomass, whereas the latter implies fulfilling a suite of additional criteria, including the restoration of age structure, evolutionary mechanisms, and behavioural traits. Murawski's message, echoed by subsequent presenters, clarified that "rebuilding" has a much longer time horizon than "recovery". Moreover, these two terms reflect different philosophies. The typical prime objective of fishery management is to restore stocks to some target fishable biomass, largely ignoring specific biological features, such as age structure or size- and/or age-at-maturity. However, when put into a broader, ecological context, it is important to restore a stock to such a condition that it again fulfils its original ecological role in the ecosystem.

> Theme 1 *Impact of fisheries and environmental impacts on stock structure, reproductive potential and recruitment dynamics*—Chairs C. Tara Marshall (Scotland) and Toyomitsu Horii (Japan)

The subtitle of this session —"Yes we can" (rebuild the stock)— was a provocative one indeed, because although many stocks evidently have recovered in response to management measures, others remain in a collapsed state, despite implementation of recovery plans and reduced exploitation rates. Some stocks decline even in the absence of a major fishery should recruitment fail for some reason during a sequence of years (as in western-Baltic spring-spawning herring). Increasing fishing mortality could only make the decline worse, and for schooling fish, the potential negative feedback mechanism of increasing catchability in a declining stock might be worth considering. Contributions demonstrated that fisheries could have evolutionary effects on life-history characteristics (such as age-at-maturity). Modelling results indicated that full rebuilding to the original state in terms of genetic and phenotypic stock structure could be extremely slow, much slower than the estimates of stock biomass recovery alone would suggest. To understand fully the recovery process of different stocks, a variety of approaches might be required. For example, for species with specific spawning grounds and time-varying maturation schedules, such as herring, well-documented information on meta-population structure, along with an understanding of drift patterns of the larvae in relation to the distribution of their natural enemies, might be required to understand the trajectories of the meta-population as a whole during both the collapse and the recovery. Equally important is a process-based understanding for estimating future rates of recovery. Uncertainties in these estimates could be reduced by critically comparing long-term datasets for a variety of species, regions, and exploitation rates.

Other presentations in this session addressed how exploitation has affected recovery rates through effects on demographic structure and reproduction (e.g. North Sea plaice) or on genetic structure and life-history traits (e.g. Barents Sea cod). To the extent possible, both such effects should be disentangled from environmental effects on individual growth of individuals and reproduction (e.g. Gulf of St Lawrence cod) or recruitment and mortality (e.g. meta-analyses on cod, herring, and haddock). Although models could provide useful insights regarding historical performance, their predictive abilities should be tested rigorously. New sources of information (such as derived from data-storage tags, genetic markers, detailed fecundity studies regarding skipped spawning, and studies of maternal vs. paternal effects) have the potential to challenge conventional assumptions about spatial structure and reproduction.

Theme 2 *Trophic controls on stock recovery*—Chairs Axel Temming (Germany) and Bjarte Bogstad (Norway)

This session concentrated on multispecies interactions. Recovery scenarios for the Baltic Sea established that the long-term perspectives of cod, sprat, and herring depend largely on environmental conditions: the strength of the inflow of oxygen-rich saltwater directly affects the zooplankton composition, as well as the "reproductive volume" available for cod (i.e. the water mass where the eggs and larvae could survive). Simulations demonstrated that if the inflow remains low, as is currently the case, herring will remain in a nutritionally poor state. Because the cod stock in the central Baltic Sea is recovering—largely owing to reduced fishing mortality and somewhat stronger year classes—increased predation by this stock could reduce herring and sprat stocks to a state where the fishery on these species has to be greatly reduced or even terminated. The recovery of the cod stock could be slowed down at some stage by cannibalism, but this effect is supposed to be less pronounced during the early phases of recovery, because the spatial separation between juveniles and adults is stronger when the number of adults is relatively small. A similar mechanism was also suggested for hake in the Bay of Biscay.

The multispecies model for the North Sea demonstrated that the system is now controlled by mid-sized predators, such as grey gurnards and horse mackerel, which partly have taken over the role of cod as a main fish predator. These two species prey increasingly on 0-age cod and herring. The models also revealed that the system as a whole recovers slower than expected based on single-species assessment, because of cannibalism. Moreover, recovery of North Sea cod depends largely on the predation on juveniles by grey gurnard, which in the absence of cod has increased its biomass substantially. However, should the cod happen to recover, cascading effects could be expected, and a number of other stocks might decline, especially predators operating in the middle of the foodweb (e.g. whiting and haddock) and important prey species (e.g. Norway pout and herring, and possibly also *Nephrops* and brown shrimp).

The case of the Pacific herring is a special one because several of the local populations have so far not recovered, although fishing mortality has been kept relatively low. The recovery of Pacific herring appears to depend largely on environmental conditions. A decrease in food availability for immature fish over the past two decades could have played a role. Moreover, the recovering Pacific sardine could be competing with herring for food, whereas marine mammals keep the natural mortality high.

In the Barents Sea, the capelin stock, a prime prey species of Northeast Arctic cod, collapsed three times within the past 25 years. However, these collapses were not driven by fishing; they appear to have been induced primarily by predation on capelin larvae by juvenile herring (although an abundance of small herring does not necessarily result in capelin recruitment failure). The effects on the ecosystem have been far-reaching. During the mid-1980s, strong negative influences have been observed in cod, harp seals, and seabirds. In response to the decline of capelin, cod became more cannibalistic, growth slowed markedly, maturation became delayed, fecundity was reduced, and several mature fish might even have skipped spawning.

Theme 3 *Methods for analysing and modelling stock recovery*—Chairs Ana M. Parma (Argentina) and Laurence T. Kell (Spain)

This session had as the overarching theme uncertainty and how to cope with it, raising the following questions. Do we have the right tools and methods? Which uncertainties do really matter and how should they be addressed in the formulation and evaluation of rebuilding plans? How should a recovery process be tracked in data-poor situations? To answer these important questions, new indicators might have to be developed. Indicators could be biased, because of inherent, systematic errors; under such conditions, meta-analyses could be helpful. For the Baltic Sea, a biological "Ensemble Model Approach" was presented, which compared predictions from an array of existing models to ascertain whether these exhibit divergent properties or result in robust advice. Using different models within the same framework, the sensitivity of different assumptions could be tested.

For the evaluation of management strategies, and to allow for greater management support, the knowledge gathered through different kinds of process-orientated research must be integrated in the operating models, so that the effects of all kinds of uncertainties on the performance of harvest control rules may be investigated. Indeed, uncertainties about most processes evaluated so far do matter. They affect the conclusions about management performance, particularly about single-species management in an environment characterized by multispecies dynamics.

Uncertainties about potential responses of fishers and about the influence of environmental variables also affect the extent and responsiveness of fish stocks to the management measures imposed. Uncertainty is further confounded because of interactions among all its different sources.

In respect of the advisory role of scientists, an important question remains: how much of all uncertainty should be presented to management authorities? Expressing too much uncertainty could render the advice useless and might erode the stakeholder support; expressing too little could erode the credibility of science when, for instance, overly optimistic predictions turn out to be wrong. One potential approach to address this dilemma is to report advice such that a certain management action is expected to produce recovery to some benchmark stock level over a specified planning horizon with some estimated probability. This tactic would seem to be an improvement on simply reporting a range of uncertain outcomes. Nevertheless, tools already available allow for integrating existing and non-existing knowledge and for converting uncertain science into practical advice for management support. Whether we are currently applying these tools to a satisfactory level is another matter.

Theme 4 *Social and economic aspects of fisheries management and governance*—Chairs Denis Bailly (France) and Douglas C. Wilson (Denmark)

The goal of recovery plans might not be conservation, but rather restoring business opportunities for fishers. Bioeconomic models demonstrate a huge potential for restoring economic rent, if only the lessons learned from stock collapse result in improved post-recovery management efficiency. When providing multiannual guidance on recovery plans, recognition of the importance of limiting interannual variation in catching opportunities and of progressive rather than abrupt implementation of management changes is beneficial for the industry, though at the price of delayed stock recovery.

Once stocks recover, restoring fisheries becomes big business, with the prospect of higher revenues and greater employment opportunities in the harvesting and processing sectors, respectively. It is noteworthy that recovery of stocks—as well as depletion—often coincides with large changes in predator–prey abundances; therefore, catch opportunities could shift among fleets and eventually redistribute wealth. Individual fishers often want to have their claims for entitlement to fish on recovered stocks to be taken into account; to achieve this, they could negate the best science and the best management system by exerting political pressure. Although the fishing industry is not a homogenous entity, there are well-organized groups by métier, by sector, and/or by community.

Viewed from the other side, the managers do not all hold the same views or values about key objectives and have to consider other claims as well, such as conservation, social aspects, etc. In addition, the management framework also concerns the maintenance of tradition, culture, norms, and social networks (social capital) that are key to social organizations and social community development. Moreover, fishing communities are not equally resilient to change; some can readily adapt, whereas others might be vulnerable because of their high dependence on the resource (because of gear specialization, few economic alternatives, ageing population, and/or low education).

Therefore, community profiles, baseline assessment on social aspects, and social impact assessments are useful tools to help design policies. However, the questions remain how to incorporate these aspects in the overall assessments, how to implement the process, and how to develop stakeholder participation in such a way that the community at large feels responsibility for recovery plans and adjusts to the course being taken.

Because stock collapse usually happens because of a failure of governance in respect of controlling fishing effort, recovery plans are not likely to work without rethinking the governance structure. Effective governance should reflect the views expressed by all parties—fishers, managers, scientists, and NGOs. This participatory approach requires a great amount of flexibility to allow different groups to take part in the decision-making process. The overarching objectives must be defined at a high service level, but the operational implementation could be left to lower service levels.

Theme 5 *Management and recovery strategies*—Chairs Joseph E. Powers (USA) and Fritz W. Köster (Denmark)

Frameworks for management strategy evaluation are still under development. They could comprise aspects ranging from stock productivity to fleet structure, catch composition and related economics, and technical measures (e.g. gear regulations, spatial/temporal closures). The models used are generally sensitive to environmental change, spatially explicit, driven by economics, and capable of handling uncertainty. However, they currently mostly lack species interactions and the associated probabilities of failure.

During this final theme session, the pragmatic question was raised whether such detailed modelling is needed to implement a successful recovery plan, given that the basic problem is the need for a rapid reduction in fishing mortality. In addition, how should fishing mortality be reduced—should it be by effort reduction, by cutting TACs, or a combination of both? Additional considerations are whether such actions should be accompanied by (temporal) area closures, gear restrictions, and/or other technical fixes and whether the answers to these questions are stock-specific, ecosystem-specific, or universal. Although these questions cannot yet be satisfactorily answered, it is imperative that, first, clearly defined management objectives and objective performance criteria must be developed and agreed upon, followed by rapid reduction of fishing mortality tuned to the specific life-history characteristics of the species in question.

Panel discussion

The final day of the symposium included a panel discussion among eight experts, representing science through PICES and FAO, the fishing industry, NGO conservation groups, and management authorities through the European Commission and DFO (Canada). The discussion was moderated by Ralf Röchert, an independent professional journalist and biologist. The session was divided into five blocks, representing the five theme sessions. Each block opened with a brief summary of the principal findings by the corresponding session chairs, followed by comments from the panel members and the audience. The panel discussion ended with a summary by Steve Murawski, who had also given the keynote address.

The panel appreciated the overwhelming evidence brought forward that collapsed and severely depleted fish stocks can recover and be rebuilt, although the process might be slower than often thought previously, especially if ecosystem shifts had taken place in predator–prey relationships. Rebuilding the life history, age composition, stock structure, spatial distribution, and ecosystem functioning of a stock could take considerably longer than the recovery of the stock biomass to a level that allows sustainable exploitation. Stock-recovery plans represent the most widespread, large-scale wildlife management experiments ever undertaken, and it is imperative that their effectiveness or otherwise be well-documented through monitoring and that they should be archived and widely communicated. Because the system occupied by a stock might have changed from the state before depletion, recovery plans must be adaptive. However, they should not assume lower rebuilding targets based on recent productivity rather than historically experienced productivity, until monitoring provides justification for revised targets. The productivity of depleted stocks might increase to historic levels, though slowly, as the evolutionary effects of size-selective fishing are gradually reversed and ecosystem functioning restored.

The short-term socio-economic effects associated with rebuilding fish stocks are considerable, but should be offset by increased benefits over the longer term. These downside losses and upside benefits have to be communicated to the fishing industry and to the public in a clear and transparent way. If fishers could secure access rights to the fishery of the future, they might be more willing to bear the current costs. Stock rebuilding invariably implies fewer fishers in future and substantial transition costs will exist. However, catch rates should increase and earnings should be higher. These effects should be understood and anticipated in advance.

If fisheries-induced evolutionary changes have taken place, or environmental change has altered the productivity and demography of a species or has altered ecosystem structure, restored stocks could differ markedly from those before depletion. Therefore, recovery to former biomass levels and restoration of stock structure might not always be possible, owing to dominance shifts in the ecosystem and/or to evolutionary effects.

A precautionary and adaptive approach might be required to avoid delays in taking effective action, not only for stocks already in dire states, but to prevent those exhibiting signs of over-exploitation and decline from collapsing.

Although the outlook for recovery plans is promising, fishery science has to invest more in their further development; they should integrate information on environmental change, ecosystem functioning, and habitat change to improve forecasts. In addition, there is a pressing need to extend stock assessment and management advice to incorporate socio-economic implications. To achieve this, fishery science has to change from the single-species assessment and advice (which remains the dominant paradigm) to a more holistic ecosystem assessment, where stock abundance is only a part of a dynamic ecological and socio-economic matrix. This is not a new appeal and various ICES and PICES Working Groups have taken up this challenge. If taken seriously, such a shift in the expectation regarding the deliverables of fishery science implies the need for a substantial increase in scientific resources, beginning with the funding needed to collect the additional field data required for implementation of a more holistic approach.

doi:10.1093/icesjms/fsq039