Scientific Basis for Fisheries Policy and Management

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Empirical Foundations

The science foundations of fisheries policy and management have a history of over a century. By the 1920s there was already concern about fisheries that had failed at least on local and sometimes larger scales, and a desire to avoid such failures. From the outset the science foundations were strongly empirical and at best weakly theoretical. This emphasis on empirical approaches was not because fisheries science was necessarily anti-theoretical. Rather, potentially relevant theoretical areas, such as ecology and oceanography, were themselves in their infancy. Established theoretical principles were few, and their relevance to applied problems was largely unexplored. Nevertheless some of the applied problems of unsustainable practices in fisheries were already urgent, and the scientists of the day were seeking ways to use available information to address practical problems.

To illustrate, the early work that eventually led to concepts such as maximum sustainable yield (MSY) came from empirical observations that as unexploited fish populations were reduced in abundance by a fishery, in many cases somatic growth rates increased, and recruitment to the fisheries at least did not decrease, and in some cases, such as many Pacific salmon, actually increased. These empirical observations began to be systematized into concepts like optimal yield and surplus production by the 1930s. Scientists of the day did explore theoretical concepts like the Verhulst equation in applied contexts, but as efforts to find increasingly powerful mathematical expressions to capture patterns emerging from the empirical data available on how fish populations changed with exploitation. From the beginning, progress was captured in mathematical equations to represent patterns in the information available, facilitating the ability to apply case-specific advances in knowledge to much wider ranges of similar problems.

This did not mean the advances in fisheries science were incompatible with evolving fields of ecological, oceanographic, and economic theory. As concepts like carrying capacity and density dependence were elaborated in ecological theory, they enhanced the ability to explain why the empirically-based tools
that were being developed in applied fisheries science could be expected to work. The important point was that the developments in fisheries science were not derived from the theoretical ecological concepts, only subsequently to be applied to real-world problems. Practice used theory as it became available, but did not wait for theory to be developed before exploring the empirical evidence as far as their creativity and experience allowed.

This pattern of a strong degree of empiricism has continued to characterize fisheries science. A powerful illustration is that increasingly strongly from the 1970s through the 1990s, severe declines or collapses occurred in several high-profile fisheries. In some cases, such as sardines and anchovies in the eastern Pacific and cod in the Northwest Atlantic, these were not the first times the stocks had shown large declines. However, after extension of jurisdiction and implementation of (for the time, cutting-edge) fisheries science as a basis for policy and management, another round of such declines, due to rapid drops in stock productivities, occurred unexpectedly. Policy and management wanted practical explanations for this new round of ‘fishery failures’, not additional theoretical concepts.

**Flexible Problem-Solving**

The hunt for explanations converged on ecosystem- and decadal-scale changes in physical oceanographic conditions and impacts of ocean physics on marine productivity. The investigations were based primarily on empirical studies of patterns in the fisheries and oceanographic datasets. Oceanographic and marine food web theory was quick to catch up, but ideas of regime shifts emerged from the empirical studies, not the reverse. The theory did not come first, prompting empirical investigations that would not otherwise have happened.

This continued importance of empirical problem-solving approaches to fisheries science, using theory when available but not waiting for it, and instead relying on information itself when theory is not yet available, has many consequences. Some consequences provide advantages for fisheries science, others may be limitations. Many of these advantages and limitations may actually be linked as co-benefits and trade-offs that characterize the science foundations for fisheries policy and management. Seeing how these co-benefits and trade-offs interact can provide insights into where fisheries ‘science’ may be heading in the near future.

Perhaps of greatest value, by not being locked into any single theoretical framework, fisheries science has retained great flexibility. The challenges to fisheries sustainability can come from many sources—environmental changes
in ocean climate or in abundance of predators or prey, technology changes, expanding or cutting back on fisheries targeting other species in the same ecosystem, changes in markets or consumer patterns, and other sources. Regardless of how comprehensive a theoretical approach to fisheries science might be, challenges will arise that are outside the scope of the theory. An empirically-based approach to fisheries science has no conceptual problem in simply shifting focus as needed to address new challenges as they arise (there may be other limitations, discussed below). Were fisheries science strongly constrained by any particular theory, addressing problems out of that scope could be either resisted or require a major retrenching of thinking.

**Limitations—Integration and Forecasting**

The limitation of this great flexibility in the ability of fisheries science to shift focus as new applied problems arise is that there is no obvious pathway to integrate new knowledge with currently established knowledge, as new things are learned. Integration is usually possible, but often ends up being approached in an *ad hoc* way because no single pathway for integration emerges in the absence of a coherent theoretical framework. This can result in inherent incompatibilities co-existing within the general science framework being used by fisheries policy and management. For example, a well-managed fishery on a species with a typical groundfish life-history reaches MSY at about 40 percent of unexploited biomass ($B_0$), whereas the International Union for Conservation of Nature (IUCN) criteria for risk of extinction interpret a population reduced to 30 percent of its starting numbers in three generations as ‘threatened’; most assessments would have sufficient uncertainty that a 95 percent confidence interval on biomass would be wide enough to include both values. These apparent incompatibilities, due to different piece-wise theories, pose real challenges to policy and management of fisheries.

A second limitation of the lack of any comprehensive theory of fisheries science is that the ability to forecast is limited. When a single theory is applied to a fisheries science question, it is possible to develop predictive equations that can extrapolate the trajectories of the fish population as far into the future as the independent variable(s) in the equation can be forecast. This is occurring, for example, with predictions of future distributions and productivities of fish.

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1 The IUCN Red List of Threatened Species, 2001 Categories & Criteria (version 3.1), http://www.iucnredlist.org/static/categories_criteria_3_1.
populations under various scenarios of climate change. Such forecasts can be highly valuable in planning adaptive strategies for fisheries in a changing climate.

The above limitation means that such predictions explicitly do not take into account the many other factors that affect fish population dynamics, because they are explicitly not part of the basis for these predictions. This has a co-benefit that users of these forecasts can be readily informed of the limitations in the forecasts, and encouraged to consider them at best as partial answers to the policy questions of concern. The need to consider additional information in planning is obvious. Were the models used in forecasting presented as comprehensive and inclusive, policy-makers and management might be more vulnerable to pressures to treat the forecasts as predictive rather than illustrative.

On the other hand, keeping forecasting limited by primarily empirical relationships also limits the scope for forecasting in time and space. Empirically-based predictions are inherently strongly influenced by the initial conditions, and within a biological generation or two, or a decade of ocean climate, the dynamics of these systems mean that initial conditions have low influence and users are looking at projections of previously projected values. Without theoretical constraints on projections, uncertainty is likely to escalate and be increasingly unhelpful to policy-makers.

**Co-Benefits—Use of Data and Knowledge Systems**

An important aspect of the strong foundation of fisheries science in empirical approaches is that it highlights the dependence of progress on data quantity and quality. Limitations of this dependence are obvious. Whether done through research surveys or monitoring of fisheries, collection of data at sea or in remote freshwater sites is demanding of human and financial resources. These costs are being reduced by technological advances, but similar technological advances are being made in other applied science fields as well, leaving fisheries science still a comparatively costly endeavor.

Countering those limitations, the fact that improved data for fisheries science does get used to improve fisheries policy and management means that it is possible to show direct benefits flowing from investments in monitoring fisheries and the ocean environment. Monitoring is often an unpopular item in budgeting, so documenting the benefits can strengthen support. In addition, by relying on evidence from monitoring, science has strong incentives to watch for deviations in the data streams, and give early attention to changing
conditions. Complex and integrative theoretical models may buffer unexpected trajectories of individual input data streams, and if the science inputs to policy and management are primarily from such models, the new information in the individual data streams may not receive timely attention.

Two of the points made in this essay combine to comprise possibly the greatest strength of the empirical focus of science foundations for fisheries policy and management. When new problems emerge in a fishery—or long-standing problems rise in priority—the importance of the data streams to the capacity to advise on immediate and longer-term issues means that the adequacy of existing data streams to support advice gets scrutiny. In cases when it appears that existing data streams do not cover the new priority concern adequately, the lack of dominance of any single theoretical framework in fisheries science allows the science community to look very broadly at sources of information that can fill the voids.

This has allowed fisheries science to be receptive to other knowledge systems in cases when ‘science’ monitoring streams were not available to fill an advisory need. This broadening of the inclusion of the knowledge of local communities and Indigenous peoples with conventional science has not always been embraced quickly nor progressed smoothly. However, there have been significant advances, in some locations, to bring holders of local, Indigenous and/or community knowledge into science-based data collection systems. An example was Canada’s Atlantic Coast groundfish sentinel fisheries program, which brought together fishers’ knowledge and science following the cod fishery collapse. Successes in such syntheses of knowledge systems are accumulating quickly, and actually becoming a norm for many fisheries. Particularly when accompanied by advances in co-management of the fisheries themselves, acknowledging the value of co-creation of knowledge for co-management is a logical step. The flexibility of the science foundations for policy and management has made these steps easier for both institutions and experts to take.

A final parallel benefit is also appearing in fisheries science. Just as the flexibility of a strongly empirical approach to fisheries science facilitated ‘empirical’ being interpreted broadly as ‘knowledge-based’ rather than narrowly ‘science-based’, the lack of any single dominant theoretical framework for fisheries science is facilitating an increasingly broad interpretation of ‘science’. If rigid theoretical frameworks were to be built, these would draw on established biological, physical, and chemical theory, with little scope to incorporate social sciences. This would accordingly impede placing fisheries policy and management into a full socio-ecological system. Instead, the flexibility of the science foundations are allowing bridges to be built between the ‘natural’
and social sciences, making the foundations of policy and management both broader and stronger. Together these two pathways—broader use of the plurality of knowledge systems and greater inclusiveness of social as well as natural sciences in support of policy and management—mean the best years for fisheries science may still lie ahead.