IMPORTANCE OF FISH STOCK ASSESSMENT TO FISHERIES MANAGEMENT

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Introduction

Fisheries tend to collapse because of fleet over-capacity, leading to harvesting the stocks of fish beyond their ability to recover. Fishery collapses have been very common, creating economic, social and ecological problems of great complexity. One of the major aims of fisheries management is to avoid fleet overcapacity by directly controlling the fishing effort (input control) or by setting limits to the total catch per season/year and its biological characteristics (output control).

On the other hand, fish stocks may also be under-utilized because of fleet under-capacity. This is particularly the case when fleets are artisanal, in initial stages of development, or with poor infrastructure facilities. When fish stocks are under-utilized because of fleet under-capacity there is loss of economic diversification, revenue, employment and food security. In this situation, the prices of sea food are usually higher because domestic supply may not meet the demand.

Due to the reasons mentioned above, fisheries management must strike a balance between over-exploitation and under-exploitation (Restrepo et al., 1992). The risk of over-exploitation is the risk of management inaction, letting fishermen take too many fish from the sea thereby negatively impacting the sustainability of the stock and the fishing industry. The risk of under-exploitation is the risk of excessive management interference, setting too many obstacles to the fishermen to take fish. The fishery manager has to strike a balance by directly controlling the fishing capacity (input control) and/or by setting restrictions on the catch (output control).

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From the point of view of managers, fisheries are successful if they provide the maximum quantities of sea food in an ecologically and economically sustainable manner for indefinite periods of time. This definition of fisheries management success embodies the notion that it is necessary to avoid both kinds of risks, the risks of over- and under-utilization of fish stocks.

The key factor in the success of striking this balance is the application of fisheries management based on scientific advice coming from results of stock assessment models (Hilborn and Ovando, 2014; Melnychuk et al., 2017). This insight is widely acknowledged around the world and has crystallized as legislation in fisheries. All these legislations explicitly state that fisheries management must be based on science. The Magnusson-Stevens Act of the United States of America is even more definite, stating that all stocks exploited by commercial fisheries must be subject to stock assessment.

In the words of Gulland (1983), one of the most experienced stock assessment in the world, "*All those concerned with making policy decisions about fisheries must take into account, to a greater or lesser extent, the condition of fish stocks and the effect on these stocks of the actions being contemplated*".

Definition of Fisheries Management

Fisheries management has been defined as "The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and the accomplishment of other fisheries objectives" (Cochrane, 2002).

The Technical Guidelines on Fisheries Management (FAO, 1997) describe a management plan as "a formal or informal arrangement between a fisheries management authority and interested parties which identifies the partners in the fishery and their respective roles, details the agreed objectives for the fishery and specifies the management rules and regulations which apply to it and provides other details about the fishery which are relevant to the task of the management authority." It is a process *of considering the following components to make* decisions and implement actions to achieve goals:

- Biological considerations
- Ecological and Environmental considerations
- Technological considerations
- Social and Cultural considerations
- Economic considerations
- Considerations imposed by other parties.

Other parties would include, for example, tourism, conservation, oil and gas exploration and exploitation, offshore mining and shipping, aquaculture and mariculture, and coastal zone development for business or industry. All these can impose significant constraints on fishing activities and may be impacted by fishing activities. The fisheries manager therefore needs to be aware of such activities and of real or potential impacts in both directions.

A modern fisheries manager is required to be familiar not only with the national legislation governing fisheries, but also with international legislations and voluntary instruments dealing directly with or impinging on fisheries. There has been a proliferation of such instruments in recent decades. This process shows the highly complex nature of management, and the need for considering the above-mentioned six different but interconnected and perhaps equally important elements for developing a management framework.

Principles of Fisheries Management

Arising from the considerations discussed above, a number of key principles can be identified which may serve to focus attention on effective fisheries management:

1. Fish resources are a common property resource
2. Sustainability is paramount and ecological impacts must be considered
3. Decisions must be made on best available information but absence of, or any uncertainty in, information should not be used as a reason for delaying or failing to make a decision.
4. A harvest level for each fishery should be determined.
6. The total harvest across all sectors should not exceed the allowable harvest level.
7. If this occurs, steps consistent with the impacts of each sector should be taken to reduce the removal.
8. Management decisions should aim to achieve the optimal benefit to the community and take account of economic, social, cultural and environmental factors.

In keeping with the integrated nature of fisheries ecosystems, these principles cannot be considered in isolation in considering how best to manage fisheries: their implications and consequences overlap, complement and confound each other which is what makes fisheries management so demanding and challenging.

Different Types of Management

Wider examination of fisheries management framework currently existing in different countries shows that the following three approaches are being adopted:

(i) Rights-based approach

(ii) Ecosystem approach

(iii) Precautionary approach

(i) Rights-based approach

In well managed fisheries, Maximum Sustainable Yield (MSY) or Maximum Economic Yield (MEY) or yield-per Recruit (Y/R) is used as biological reference points (BRPs) to derive thresholds and targets to arrive at sound fisheries management decisions (FAO, 2006). Spawning-recruitment relationship (S-R) is used as a key element for formulating fisheries management advice. A few other empirical reference points such as long-term mean size at capture also can be used as BRPs. By using the MSY approach and BRPs, countries like the USA, Canada, New Zealand, and a few countries in the Europe are following advanced rights-based management approach to limit the catch equal to or within the total allowable catch by following catch quotas. In these countries, Total Allowable Catch (TAC) is set with reference to maintaining the biomass at or above a level that can produce maximum sustainable yield (MSY).

(ii) Ecosystem approach

In the last ten years, it has been recognized that effective fisheries management could be achieved by following ecosystem approach, in which multiple regulatory measures and management actions could be applied in full consideration of aquatic species, the ecosystems in which they live and the developmental systems that degrade the ecosystems.

Applying an ecosystem approach to fisheries management (EAFM) is considered the preferred option and the best practice for long-term sustainability of fisheries and the services that fisheries ecosystems provide to the society.

(iii) Precautionary approach

Although MSY is an appropriate basis for reference points, there are limitations of applying MSY approach in fisheries management in the absence of key BRPs like the S-R. However, non-availability of a whole range of scientific information should not deter taking management decisions. In this situation, precautionary approach should be the backbone of fisheries management. The UN Conference on Straddling Fish Stocks and Highly Migratory Stocks (UN 1995) first articulated the principle for fisheries under the following definition:

"The absence of scientific data shall not be used as a reason for postponing or failing to take conservation and management measures".

The precautionary approach requires, *inter alia*, maintenance of a flexible, resilient fishery system including the fish stock, the associated species, the fleet and the management agency regulating it. The precautionary approach emphasizes that, greater the information gaps and the amount of uncertainty, the management measures should be more cautious to avoid risks.

Whatever is the approach, stakeholder engagement in various levels of fisheries management and co-management systems are becoming popular in many parts of the world and demonstrating considerable levels of success. In its simplest form, co-management can be described as fisheries management where roles and responsibilities are shared between the government and resource users (Pomeroy, 1994).

Breadth of Stock Assessment

Stock assessment is sometimes viewed as a rather narrow biological discipline that might be summarized as "the interpretation of commercial catch to estimate potential yields". However, stock assessment is much more than this. First and foremost, stock assessment involves understanding the dynamics of fisheries. This recognizes that fisheries are dynamic entities that will respond over time to management regulations, and to extrinsic factors. Modern stock assessment is not just the task of making static predictions about sustainable yields. It should also involve making predictions about how policies should be structured in order to deal with the unpredictable changes that will inevitably occur.

Fisheries are also much more than fish catch. Fishermen are an important component of fisheries, and stock assessment must take into account how fishermen will respond, and also make predictions about things important to fishermen such as catch per unit effort. Processing and marketing are also very important components of the fishery system.

Importance of Stock Assessment to Fisheries Management

Scientists strive to increase the types and amounts of data collected from fisheries and research projects in order to improve the accuracy of stock assessments. Fisheries managers then consider results of the stock assessment when taking management action, which in turn may affect stock abundance or productivity (Fig. 1). If a stock is overfished, actions need to be taken to reduce fishing pressure. This allows the stock to rebuild to an acceptable level and promotes a healthy fishery in the future. On the other hand, if a stock is healthy, managers take steps to ensure the stock is harvested at a level allowing for long-term sustainability. Because stock assessments are directly linked to management actions, it is important to understand appropriate uses of data, different options for analyses, and how to apply assessment results.

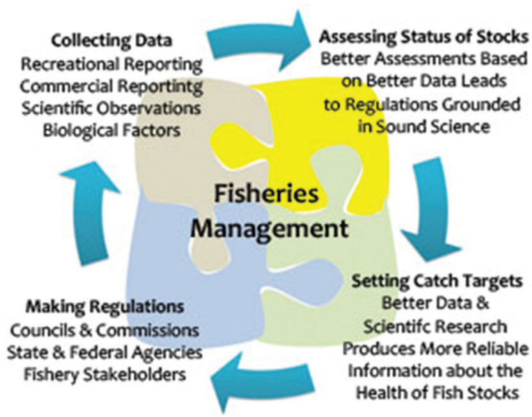

Fig. 1. Importance of stock assessment to fisheries management

The results of stock assessments serve as the basis for long-term and short-term fishery management decisions. First, the assessment provides the basis for status determinations, which entails the following:

(1) Determining whether underfishing or overfishing is occurring and determine the level that would produce maximum sustainable yield; and

(2) Comparison of current reproductive potential (usually measured as spawning biomass) to a limit level (usually set to approximately half the level that would produce maximum sustainable yield) as a measure of stock depletion and a trigger for development of a rebuilding plan.

Second, assessments provide forecasts of the expected future catch and stock abundance associated with proposed harvest policies. Thus they provide scientific information for implementation of the harvest policy that will produce optimum yield from the fishery. Finally, the time series of abundance, mortality, and productivity produced by single-species stock assessments provide input to ecosystem food web models.

Changing Role of Assessment in Fisheries Management

Commercial fisheries usually develop initially through a dynamic process that involves several distinct stages. A generalized diagram of these stages is shown in Figure 2.

(i) First, there is discovery of a valuable stock. This is the predevelopment of the fishery.

(ii) Second, there is a period of rapid growth of fishing effort.

(iii) Next, the fishery reaches full development, where yields are near or perhaps a little above a long-term sustainable level.

(iv) The rapid development results in fish stock reduction and more fishermen compete for the remaining fish.

(v) The fishery often then enters an overexploitation stage, which is followed by a collapse. The stock may or may not recover on its own during this period.

On a longer time scale, technological innovations may result in increased fishing success and attraction of more fishing pressure and hence a repetition of stages four and five of development, unless fishing effort is carefully managed through each technological transition. The extent to which the collapse is severe, or the fishery does not collapse at all will depend on the price of the fish product, the delays in investment, the extent to which fishing success declines as abundance declines, and whether regulatory agencies act to reduce effort or catch before a collapse occurs.

Fisheries management should consider quantification of these different phases of fisheries for taking decisions. (i) The most important management as well as assessment question is, what level of fishing pressure should be permitted at an initial stage of fisheries development. On a sustainable basis, is the stock likely to support 10 boats or 100 or 1000? In the early development phase, an order of magnitude of assessment, even if it is a rough estimate, will be of considerable value. This will permit precise estimates of assessment later in the development.

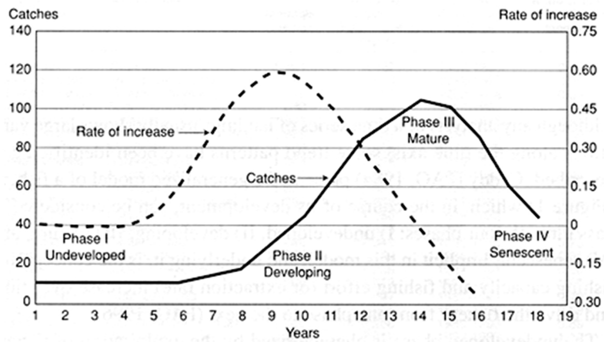

Fig. 2. An example of different phases of fisheries development (Source: FAO)

(ii) A key role of stock assessment during fisheries development is to provide regular updating and feedback of population parameters and estimated potential into the decision making process. Systematic and regular assessments will provide good early warnings of overfishing and help avoid overcapitalisation. A simple method of assessment as the fishery develops is to monitor the relationship between the fishing effort and catch and plot a graph as shown in Figure 2. As the catch reaches the top of the curve and starts to drop, it shows that the MSY has been reached and it is time to reduce the fishing effort.

(iii) When the fish stocks are overexploited, the key role of stock assessment is to quantify the choices as precisely as possible. How to rebuild the stocks? Should it be through reducing fishing effort, if so how much? How long it will take for the fisheries to rebuild? In this situation, it is important to predict how the stocks will respond to new management initiatives. A classic role of stock assessment would be to provide, based on available information, reasonable prediction about such circumstances.

Uncertainty in Stock Estimates Affects Fisheries Management Decisions

Through stock assessments, scientists aim to determine parameters such as stock size and fishing mortality rate. In reality, the estimates are not precise and they are the most “likely” values. In fact, a wide *range* of values may exist. In order to make sense of the range of possible values, assessment models produce an estimate of the uncertainty about these values. Often, uncertainty is simply a range within which the true value may lie. That range is called a confidence interval or confidence bound. The wider the confidence interval, the more uncertainty exists about where the true value lies. For example, a stock assessment might determine that the current year’s biomass equals 100,000 tonnes with a 95 percent confidence interval of 80,000-120,000 metric tonnes.

Uncertainty often exists in the information being input into a stock assessment model. What is the true natural mortality rate? Are catches fully accounted for or some might be missing? Are there errors in the way a fish's age or weight is estimated based on its length? Are fish migrating into or out of the stock?

Other uncertainties arise from the choice of stock assessment model. No model can fit the data perfectly because no model can possibly capture the true complexity of the system. Is there a relationship between stock size and recruitment? Does a fish's vulnerability to the fishing gear change each year? Does natural mortality vary from year to year? The goal is to capture the general trends as accurately as possible. Some statistical or estimation uncertainty is inevitable.

Estimating uncertainty allows decision makers to know how accurate the point values may be, and allows them to choose their actions appropriately. For stocks with greater uncertainty, the true status of the stock will not be clear. A stock with greater uncertainty cannot be managed like the one with lesser uncertainty. This is because it is more likely that the stock with greater uncertainty is already close to or even below its biomass threshold. Formally incorporating this uncertainty to predict the results of management actions is called risk assessment.

As with stock assessments, the goal of risk assessment is not to provide a single solution to stock management, but rather to provide decision makers with the information necessary to effectively compare various choices. Such risk assessments are often included within a stock assessment to predict a stock's response to different levels of fishing pressure. While a stock assessment cannot remove or incorporate all uncertainty, it should explain how uncertainty is incorporated and why it may be ignored. It should also test the sensitivity of the model to any assumptions that were made.

Stock assessments are merely tools. They cannot produce concrete decisions about how to manage a stock. They cannot tell a decision maker which management options are right and which are wrong. Rather, the stock assessment is designed to give managers and decision makers information about the current status of a stock relative to its biological reference points. It provides them with information about how the stock might respond to future management actions. Choosing between management options is ultimately the role of the manager. Ideally, a careful and complete stock assessment will provide the manager with the necessary information to manage the stock successfully into the future.

Summary

The choice of fisheries management is not whether to do stock assessment, but how best to do it. Stock assessment involves understanding and making predictions about the response of fisheries systems to management actions. Stock assessment helps managers to make

choices in the dynamic fisheries systems in the fact of uncertainty (Hilborn and Walters, 1992). The role of stock assessment is not to make the best guess on MSY, but rather help design a fisheries management system to understand the dynamics and respond to the variabilities.

Suggested Reading

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