Stock Assessment 101: Current Practice for Tuna Stocks

By
Victor Restrepo

Chair, ISSF Scientific Advisory Committee

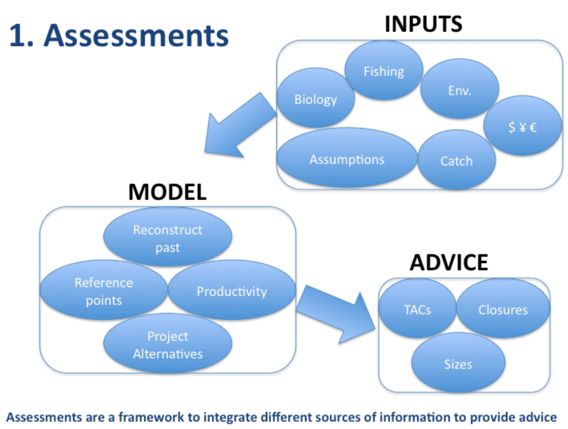
January 2011

NOTE: This document is meant to be a simple introduction to stock assessments intended for the general public. Readers interested in more details should refer to the specialized literature on the subject.

Q. What is a stock assessment?

A stock assessment is a process whereby scientists analyze a variety of relevant data about the fisheries, the species of interest and other variables (such as economic or environmental ones) in order to evaluate the impacts of the fisheries on the stock or population.

Stock assessments are not meant to be a research tool (although they can be); they are meant to provide useful information for fishery managers to consider. In many cases, stock assessment models are also used to estimate the likely impacts of alternative management options.



A stock assessment model uses the information available over a number of years (in many cases since the beginning of industrial fisheries) and reconstructs the evolution of the population and of the fisheries during this time period. By estimating how the population has responded to different levels of fishing, it is possible to predict how it might respond in the future under different management scenarios.

Stock assessment is not an exact science. There is much uncertainty due to incomplete (or even biased) data, natural variability and the inability of simplistic models to fully capture a complex reality. Fishery managers need to take this uncertainty into account

Suggested citation:
Restrepo, V.R. 2011. Stock assessment 101: Current practice for tuna stocks. ISSF Technical Report 2011-01. International Seafood Sustainability Foundation, McLean, Virginia, USA.

when making decisions. In many ways, this is similar to what successful business managers do in using indicators to track the performance of the company's finances, labor, operations (throughput), and considering legal and regulatory risks.

Q. What is a stock?

A stock results from management partitioning the population of a species into time-space sub-units that have some degree of coherence biologically and/or ecologically (like genetics, vital rates, spawning or feeding grounds or migratory pathways). This partitioning is done so as to avoid the potential negative effects of an over-concentration of fishing mortality on just a portion of the population, and to increase the sustainable yield from the population as a whole. In some cases, the stock and the population are the same.

Q. Who conducts the stock assessments?

The stock assessments are conducted by the scientific bodies of the tuna Regional Fishery Management Organizations (RFMOs). Each RFMO is structured and mandated in a slightly different way. In the case of IATTC, staff members of the Secretariat conduct the analyses which are later reviewed by the Scientific Advisory Committee before being presented to the Commissioners. WCPFC is similar, except that the analyses are initially conducted by a contracted provider (SPC's Oceanic Fisheries Program). In both ICCAT and IOTC, the analyses are conducted by working groups established by their respective scientific committees that are composed primarily of national scientists.

Q. How often are stocks assessed?

Most stock assessments of tuna stocks are conducted every two to four years, but there is a lot of variation between species and RFMOs (in fact, some tuna stocks have never been assessed). The frequency with which a stock should be assessed depends on:

- The longevity of the species. Shorter-lived species should be assessed more frequently than longer-lived ones.
- The management measures in place: Scientific advice based on stock assessments is generally timed so as to match an existing management plan. For example, if conservation measures establish quotas for four years, the assessments tend to be scheduled during the year in which the plan expires.
- The status of the stock: As part of the Precautionary Approach, stocks that are overexploited and that continue to be fished heavily should be subject to closer monitoring.

Q. What are the inputs used in an assessment?

There are a number of data inputs to an assessment, as well as assumptions and modeling choices made by scientists.

Data inputs tend to be of three kinds:

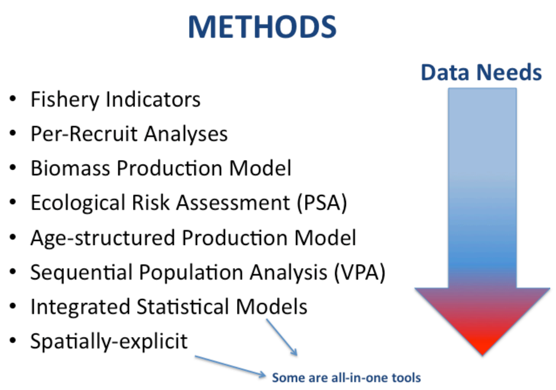
1) Data about the fisheries: Catch and catch rates (also known as CPUE or Catch per-Unit Effort), fishing effort (e.g., number of sets made), size (or weight) composition of the catch, spatial and temporal distribution of fishing.

2) Data about the fish: Any information about the life history of the fish such as growth rates, natural mortality, relationship between size and weight, size at maturity and reproductive rates, etc.

3) Ancillary information about the ecosystem, economic drivers, etc.: These are other factors that the scientists believe should be taken into consideration because they affect some component of the assessment model.

Some types of data provide information about both the fishery and the biology of the species. A good example is tagging data which can provide information on growth, behavior, and natural and fishing mortality rates.

Assumptions and model choices are often dictated by the situation. The model used to analyze the data, for example, depends on the available data. If the data are highly aggregated (for example annual catch for the entire stock, all gears combined), then only very simple models can be used. If, on the other hand, the data are available at a fine level of operational detail (such as set-by-set), then more sophisticated and complex models can be used. In typical situations there will be a mixture of aggregated data and some disaggregated data, as well as missing information or very incomplete knowledge of some biological or fishery aspect.



Ecosystem effects have been incorporated historically in stock assessments as natural variability or as simple feedback terms. However, as long-term data series of ecosystem indicators are becoming available, their use in stock assessments is becoming more common.

Q. What are the outputs of a stock assessment?

The basic component of a stock assessment model reconstructs the evolution of the population and fisheries during the time period analyzed. Typical model outputs are time series of the following:

- Recruitment to the population (the number of fish born each year)

- Fishing mortality: This is a measure of the rate at which individuals in the population die from fishing. Fishing mortality is usually estimated by age group, by year and by fishing gear (fishery).
- Abundance: The number of fish alive, usually estimated by age group and year.
- Biomass: This is like abundance, but expressed in fish weight instead of numbers of fish. Biomass is usually estimated by year.
- Spawning biomass: This is the portion of the biomass that corresponds to mature fish only, and is used as a proxy for the reproductive output of the population.
- Selectivity: This measures how vulnerable different age groups (or size groups) are to fishing by a given fishing gear.
- Catchability coefficients: These are model parameters that scale the magnitude of various inputs to various outputs. One example is that catchability links stock abundance (model output) to CPUE (model input); another example is that catchability relates fishing mortality (output) to fishing effort (input).

There are other outputs that may or may not be obtained with the same basic model. These are usually derived from two or more of the outputs above, and tend to be very important for the advice to fishery managers. For example, biological reference points such as MSY, F_{MSY} or B_{MSY} (see **Appendix 1**) which give managers a benchmark against which to compare the current levels of catch, fishing mortality and abundance.

Q. What are some of the main sources of uncertainty in an assessment?

Fisheries data are often incomplete or biased, which is a source of uncertainty that cannot always be quantified. Some of the reasons for incomplete or bad data include:

- Insufficient sampling due to insufficient resources
- Historical data gaps (insufficient resources)
- Changes in fishing technology and techniques over time that are not recorded
- Limited Research on life-history and behavior
- Mis-reporting (for example, due to IUU fishing)
- Effects of and on the ecosystem

In addition, the behavior of fish and fishing fleets (and the interaction between them) is very complex and often highly variable. Coupled with insufficient sampling of fish, fisheries and ecosystems, this results in uncertainty being a common feature in stock assessments.

Q. How is uncertainty quantified and expressed?

Scientists use statistical tools to measure uncertainty. In general, these try to measure how tight is the match between a model's prediction and the observed data: The tighter the "fit", the lower the uncertainty.

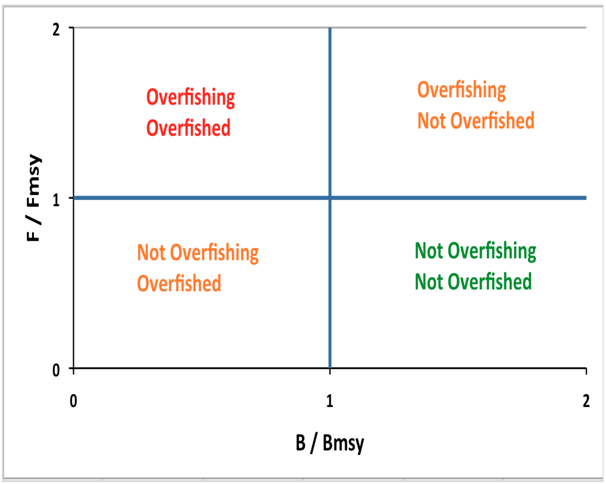
In addition, scientists sometimes use different types of models (and alternative sets of data) to see how sensitive the results can be to these choices.

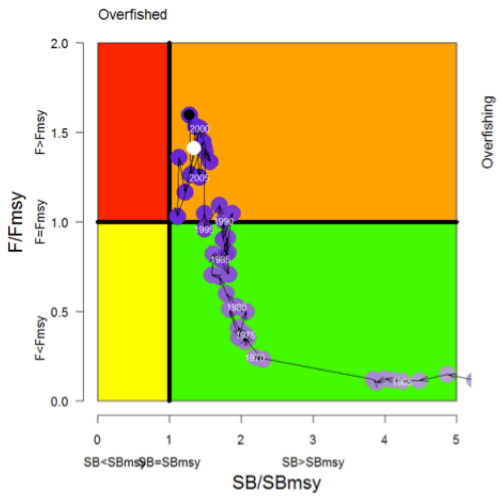
Uncertainty in assessment results can be expressed by a variety of methods. When different models are used, one simple way is to plot the results (for example, the abundance trajectories over time) from the various models. When viewing such results, however, stakeholders should be careful to recognize that not all of the models are equally likely or realistic. For this reason, scientists sometimes weigh the outcomes from different models by some measure of how likely or realistic they are.

Q. What is a Kobe Plot?

The so-called "Kobe Plot" (the name derives from the original joint meeting of the tuna RFMOs in Kobe, Japan, but now from a subsequent series of meetings in what is known as the "Kobe process") is a way of summarizing stock assessment results in a graphical way that has become widely used. On the X-axis, the plot represents biomass (or spawning biomass), expressed relative to B_{MSY}. And, on the Y-axis, it represents fishing mortality relative to F_{MSY}. See **Appendix 1** for more information about B_{MSY} and F_{MSY}.

The plot offers a simple way in which managers can quickly infer if the stock is in "good" or "bad" shape, depending on where it falls in one of four quadrants in the plot. A value below 1.0 on the X-axis means that the biomass is below B_{MSY} (in most cases, RFMOs refer to this as the stock being "overfished"). And, a value above 1.0 on the Y-axis means that the fishing mortality is above F_{MSY} (meaning that the stock is "being overfished" or that "overfishing is occurring").



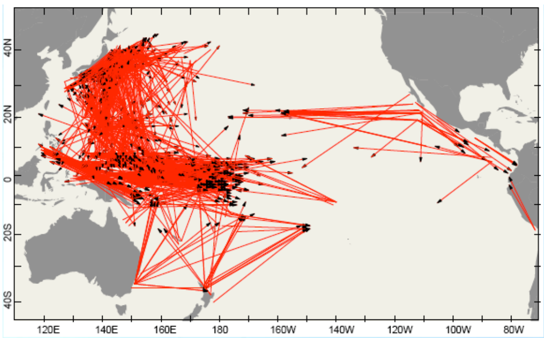


The Kobe plot above on the right is an example (for bigeye tuna in the western and central Pacific Ocean). Each purple dot shows the relative situation of the stock in different years. In the more recent time period (the darker purple dots), overfishing has been occurring. The white dot shows the current situation of the stock, i.e., its status in the last year of the assessment data analyzed.

Q. How can stock assessments be improved?

Data, data, data! The state-of-the-art of fish stock assessment models today is quite sophisticated and, for the most part, improving stock assessments does not depend on improving modeling techniques. The limiting factor in stock assessments is the quantity and quality of data available for the fish, fisheries and their ecosystem. Even in the tuna RFMOs that count with excellent data sets for some fisheries, there are substantial data deficiencies for other fisheries. These are a few ways in which data can be improved:

- Increased sampling intensity to cover all fisheries and their associated ecosystems. All ecosystems and some fisheries have inadequate sampling coverage. For example, many artisanal fisheries are poorly sampled and even such basic statistics as total catch are poorly known. Developed nations should assist developing ones to improve their capacity to meet sampling and reporting obligations.
- Increased observer coverage. Observer data can be an important complement to other sampling activities, such as logbooks, and can serve as a means of validating other sampling sources.
- Enhanced tagging programs. Scientific campaigns where fish are tagged and released, and later recovered in fishing operations, are very valuable as they provide useful information to the stock assessment models.
- Enhanced research on fish and fisher behavior, to (1) improve our understanding of the effects of environment on fish population dynamics, (2) better quantify fishing effort (i.e. to find measures of fishing effort that are directly proportional to fishing mortality), and, (3) better assess key parameters such as catchability (which characterizes the interaction between fish and fishers).
- Increased involvement by the industry. The industry, both fishing and processing sectors, can help member governments of RFMOs do their job more effectively and efficiently by ensuring that their operations are sampled and reported adequately and in a timely basis. In many cases, the industry has historical records that could be useful to an assessment but that were never collected by government agencies.



APPENDIX 1

MSY BENCHMARKS

Maximum Sustainable Yield (MSY) is a reference point that helps guide fisheries management. All of the Tuna RFMOs have as one of their management objectives the aim to maintain tuna populations at levels that can produce MSY.

Definitions

MSY can be defined as "The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. (For species with fluctuating recruitment, the maximum might be obtained by taking fewer fish in some years than in others.)"

F_{MSY} (also "Fishing Mortality at MSY" or "MSY Fishing Mortality Level"). This is the level of fishing intensity that, if applied constantly year after year, would result in MSY.

B_{MSY} (also "Biomass at MSY" or "MSY Biomass Level"). This is the stock size (biomass) that would result on average if F_{MSY} was applied constantly year after year. BMSY is sometimes measured by the total biomass of the stock and sometimes by the biomass of the spawners ("spawning biomass").

"Kobe Plot" (also "phase plot" or "Stock status plot"). This is a plot used to summarize the status of a fishery relative to MSY-based reference points. The X-axis corresponds to the ratio B/B_{MSY} and the Y-axis corresponds to F/F_{MSY}. The four quadrants of the plot are usually colored for simplicity, with Green corresponding to [$F<F_{MSY}$; $B>B_{MSY}$], and Red corresponding to [$F>F_{MSY}$; $B<B_{MSY}$].

Notes

- If F_{MSY} were applied constantly, year after year, neither the stock biomass nor the catches would be constant. The biomass would fluctuate around B_{MSY} and the catches would fluctuate around MSY. The degree of these fluctuations would depend on the characteristics of the stock. The fluctuations would be greater for stocks with high inter-annual variability in recruitment (basically, the number of fish that are born each year).

- MSY, F_{MSY} and B_{MSY} levels for a given stock can change due to the selectivity of fishing gears ("selectivity" means the size range that a particular fishing gear tends to catch in a given area and a given season). Generally, if the combined result of all fisheries tends to yield larger fish, MSY will be higher. Some tuna fisheries have experienced substantial changes in selectivity over time as a result of the introduction of different gears or fishing operations. For example, the MSY for bigeye tuna in the western and central Pacific Ocean has been reduced to about one-half of its highest historical level.

- MSY, F_{MSY} and B_{MSY} levels for a given stock can also change due to environmental reasons. For example, environmental changes could affect the average level of recruits to the population, or the average growth rates, or average natural mortality rates, etc. Sometimes these changes cannot be easily explained. When they are abrupt, scientists often refer to "regime shifts", meaning that there was a large change in the ecosystem that affected the stock.

- MSY-based reference points are estimated during the stock assessment process. There are different methods that can be used for estimating these quantities. For most tuna stocks, the estimation involves a combination of two types of models:

a) A Yield-per-recruit and Spawner-per-recruit model. This model is used to predict how different levels of Fishing Mortality will affect the catch (and the reproductive output) that is obtained, on average, from a fish in the population (from each recruit).

b) A stock-recruitment relationship. This model relates recruitment to the reproductive biomass of the stock. It is used to predict the number of recruits that will result, on average, at different population sizes.

Typically, due to data limitations and environmental noise, the application of the second type of model requires scientists to make assumptions. Thus, the estimation of MSY-based benchmarks is highly sensitive to the assumed relationship between spawning biomass and recruitment.

- When a stock falls somewhat below B_{MSY}, it does not mean that a collapse is imminent. It means that it may be falling below the level at which managers intend to maintain it. The stock should be closely monitored and management measures should be strengthened as needed in order to ensure that it rebuilds again to B_{MSY} or greater. However, if a stock falls substantially below B_{MSY}, e.g. to less than one-half of B_{MSY}, there will be a much increased risk of a serious collapse and managers need to take drastic action to ensure stock rebuilding.

- If managers are to embrace the Precautionary Approach, they should manage fisheries so as to ensure that fishing mortality does not exceed F_{MSY}. Given that there is uncertainty in stock assessment results, F_{MSY} should not be their target, because it would be exceeded half of the time just due to that uncertainty. Furthermore, there are benefits to be obtained if fishing mortality is kept somewhat below F_{MSY}. For instance, the economic rent of the fisheries is usually maximized at a lower level of fishing mortality; in addition, the resulting stock biomass will be higher, providing further conservation benefits.