Fish Stock Assessment 101

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Part 1—Data Required for Assessing U.S. Fish Stocks

May 23, 2012

Why Do We Conduct Fish Stock Assessments?

NOAA Fisheries' scientific stock assessments are key to fisheries management. They examine the effects of fishing and other factors to describe the past and current status of a fish stock, answer questions about the size of a fish stock, and make predictions about how a fish stock will respond to current and future management measures (see the Marine Fisheries Stock Assessment Improvement Plan). Fish stock assessments support sustainable fisheries by providing fisheries managers with the information necessary to make sound decisions.

What is a fish stock?

A biological fish stock is a group of fish of the same species that live in the same geographic area and mix enough to breed with each other when mature. A management stock may refer to a biological stock, or a multispecies complex that is managed as a single unit.

Why Are Fish Stock Assessments Important?

Fisheries in the United States contribute significantly to the American economy and generate over 1.5 million jobs economy-wide. Healthy fisheries also provide recreational fishing opportunities to millions of Americans. To continue enjoying these benefits, we must carefully manage fish stocks to ensure sustainable use for current and future generations.

Stock assessments provide important science information necessary for the conservation and management of fish stocks. The Magnuson-Stevens Reauthorization Act calls for the best scientific information available to manage U.S. commercial and recreational fisheries. Approximately 500 fish stocks in the United States are managed under fishery management plans produced by eight regional fishery management councils. Additionally, coastal states and international organizations rely on NOAA Fisheries' stock assessments for the management of non-federal and joint jurisdiction fish stocks.

Stock Assessments—Designed to Answer Difficult Questions:

- What is the current status of a fish stock relative to established targets? (e.g. Is a stock experiencing overfishing? Is the stock overfished?)
- How much can fishermen catch while maintaining a healthy and sustainable fish stock?
- If a stock is depleted, what steps must be taken to rebuild it to healthy abundance levels?

Answers to these important questions help managers make the best decisions to ensure a healthy balance between sustainable fish stocks, ecosystem health, and productive coastal communities.

Data for Complete Stock Assessments—Catch, Abundance, and Biology

Stock assessments are based on models of fish populations that require three primary categories of information: catch, abundance, and biology. To ensure the highest quality stock assessments, the data used must be accurate and timely.

Catch Data—The amount of fish removed from a stock by fishing.

A national network of fishery monitoring programs continuously collects catch data and makes this information available to stock assessment scientists and managers. Sources of catch data include:

- Dockside monitoring: Often conducted in partnership with state agencies and Fishery Commissions, dockside monitoring records commercial catch receipts to give an accurate measure of commercial landings and provides biological samples of the length, sex, and age of fish.
- Logbooks: Records from commercial fishermen of their location, gear, and catch.
- Observers: Biologists observe fishing operations on a certain proportion of fishing vessels and collect data on the amount of catch and discards.
- Recreational sampling: Telephone interview surveys and dockside sampling estimate the level of catch by the recreational fishery (Read more about the Marine Recreational Information Program).

Improving Data Collection—Good Stock Assessments Require High Quality Data Inputs

How is NOAA Fisheries working to improve data collection programs?

- Electronic catch data collection for rapid access.
- Advanced monitoring equipment attached to traditional sampling gear to collect concurrent environmental information during surveys.
- Visual surveys in complex habitats using imaging systems on robotic and autonomous underwater vehicles (AUVs).
- Non-extractive (does not harm or remove samples) abundance sampling using **hydroacoustic technology**.
- Better define stock boundaries, habitat use, and fish movements by using electronic fish tags, genetic analysis, and research on the chemical structure of fish bones.

Abundance Data—A measure, or relative index, of the number or weight of fish in the stock.

Data ideally come from a statistically-designed, fishery-independent survey (systematic sampling carried out by research or contracted commercial fishing vessels separately from commercial fishing operations) that samples fish at hundreds of locations throughout the stock's range. Most surveys are conducted annually and collect data on all ecosystem components. NOAA Fishery Survey Vessels and chartered fishing vessels use standardized sampling methods to collect data the same way each year, providing a relative index of abundance over time. In some situations, catch rates by fishermen can be calibrated to provide additional abundance measures as well.

*Scientists use **fish ear bones (otoliths)** to determine fish age, similar to how tree rings tell us about tree age.*

Biology Data—Provides information on fish growth rates and natural mortality.

Biological data includes information on fish size, age, reproductive rates, and movement. Annual growth rings in fish ear bones (otoliths, pictured on right) are read by biologists in our laboratories. The samples may be collected during fishery-independent surveys or be obtained from observers and other fishery sampling programs. Academic programs and cooperative research with the fishing industry are other important sources of biological data.

Part 2—A Closer Look at Stock Assessment Models

October 10, 2012

> **What is a stock assessment?**
>
> A stock assessment is the process of collecting, analyzing, and reporting demographic information to determine changes in the abundance of fishery stocks in response to fishing and, to the extent possible, predict future trends of stock abundance.
>
> Managers use stock assessments as a basis to evaluate and specify the present and probable future condition of a fishery.

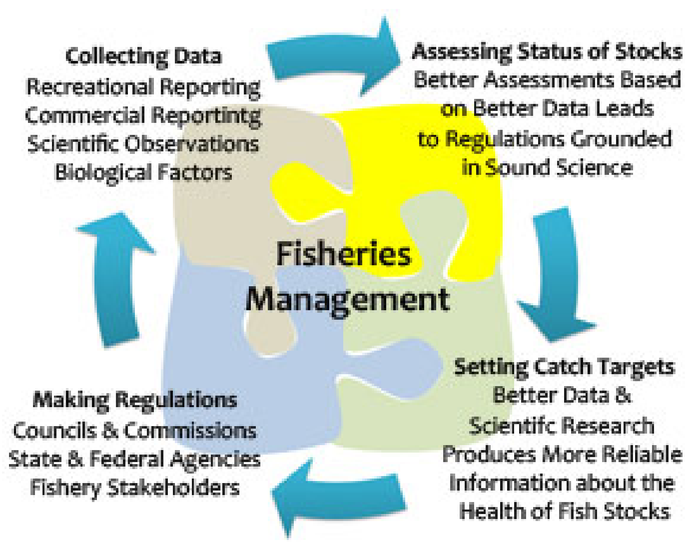
Three types of data (catch, abundance, and biology data) feed into mathematical models that represent the factors causing changes in harvested fish stocks. The models produce estimates of the fishery management factors needed for managers to make informed decisions about how to best regulate a fishery. When possible, stock assessment models include information on ecosystem and environmental effects to improve the interpretation of historical information and the precision of forecasts.

Stock Assessments Provide Scientific Advice for Sound Fisheries Management

> **What is a quota?**
>
> A quota is the maximum amount of fish (number or weight) that can be caught within a specified time period. Quotas might apply to a total fishery, multiple fishing sectors, or individual fishermen under catch share programs (i.e., individual transferable quotas).

Stock assessments are one important piece of a dynamic cycle of management aimed at preserving our ocean resources. They provide scientific advice to decision-makers on the current health and future trends of a fish stock and its fishery. Assessments also offer the technical basis for setting annual fishery harvest levels (through quotas and catch limits) and other fishery management measures.

For example, if a stock assessment model indicates that a stock has rebuilt to a healthy level, fishery managers recommend higher catch limits, longer fishing seasons, or fewer fishing area restrictions. Managers make recommendations with the intent of maintaining healthy fish populations and sustainable fisheries that provide for economically healthy coastal communities and a constant supply of seafood.



What Factors Go Into Fish Stock Assessment Models?

Fish stock assessment models represent the processes of birth, natural death, growth, and fishery catch that affect the fish stock over time. Scientists calibrate the model by using observed data from fishery catch, fish abundance surveys, and fish biology. Conceptually, this is similar to NOAA's National Weather Service dynamic atmospheric models, which use multiple weather observations to calibrate complex atmospheric models that forecasters can use to make informed predictions.

Even though fish stock assessments operate on much longer time scales than weather models—months and years rather than hours and days—they similarly combine and incorporate many different complex observations into a holistic picture of the situation.

Like weather models, most of today's stock assessment models work as computer simulations of fish populations. Hundreds of factors may be needed in complex situations involving multiple stock areas, several fishing fleets, and lengthy time series data. In the end, how closely a fish stock assessment model fits the actual data indicates the reliability of the historical estimates and future predictions for a fish stock.

More About Models:

Individual stock assessment modeling packages offer different features. The models available for assessing fish stocks range from simple to complex based on the available data for a given stock.

Scientists choose the model best suited for a stock's life history and data availability and might try multiple models to find the best possible fit.

Fish stock assessment models can be divided into two very broad categories:

Core Applications—Proven methods drive core applications. Used extensively in peer-reviewed stock assessments.

Research Models—Research models represent new methodology tested (and often developed) by NOAA Fisheries stock assessment scientists, but not yet used to complete peer-reviewed stock assessments.

Learn **more about models** and visit the **Stock Assessment Toolbox**.

Many assessment models use graphical interfaces that help standardize assessments and make it easier for scientists to work together on projects and compare their work.

A mathematical fish stock assessment model represents the demographics of a harvested fish stock and produces estimates of relevant fishery management factors. A fish stock assessment model incorporates many complex fish-related factors into a graphical representation.

Scientists use the model to graphically display many complex factors as a complete picture. They then use this picture to inform decisions about how to regulate and manage fish populations.

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The Integrated Analysis Model

Like weather models, most of today's stock assessment models work as computer simulations of fish populations. The most complete assessment model is called an integrated analysis model composed of three model layers: population, observation, and statistical.

Layer 1—Population Model: First, the population model computes the essential population factors such as stock abundance, mortality, growth, reproduction, and movement for each year, typically during the past several decades.

Layer 2—Observation Model: Next, the observation model creates predictions from the population model of data that have been measured, including survey abundance index, catch, fish size and age composition, and others as available.

Layer 3—Statistical Model: Finally, the statistical model compares the data predictions to the data observations and adjusts the factors in the population and observation model to achieve the best possible match to all the data.

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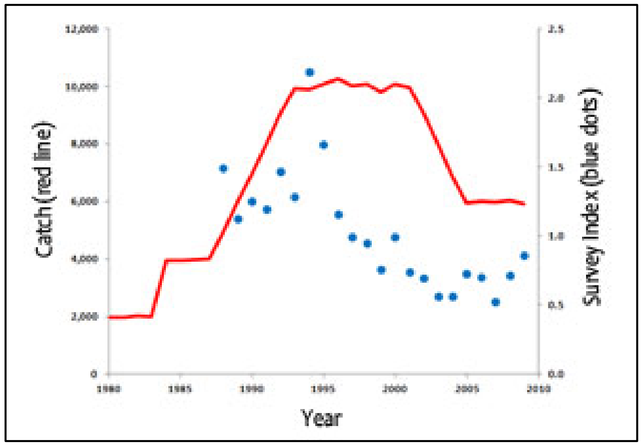
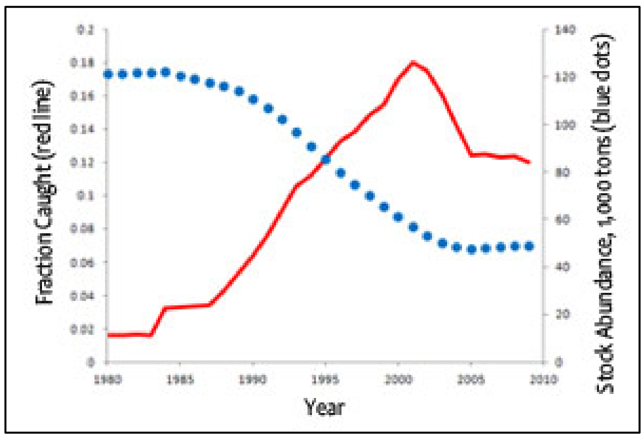
Many modern assessment models use graphical interfaces to help standardize assessments and make it easier for scientists to work together on projects and compare their work.

A Simplified Example of a Fish Stock Assessment Model Using Sample Data

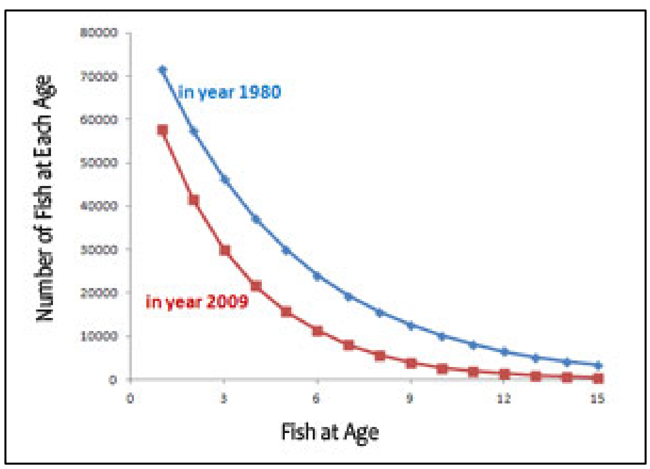
Input Data—Data on fisheries catch, stock abundance, and other important observations go into the assessment model. Here, the example shows catch data (red line) and survey index abundance (blue dots) over time.



Model Results—Mathematical simulations produce estimates of important fishery management factors. For example, assessment models estimate stock abundance (blue dots) from survey index and other data and calculate the fraction of the population removed by fishing (red line).



Management Advice—When supplementary data are available, such as information on fish size or age, scientists can calibrate the assessment model and produce additional results useful to resource managers. This example shows model results of how fishing has changed the age structure and reduced the number of older fish in a sample population between 1980 and 2009.



Part 3—Ecosystem Factors and Assessments

June 17, 2013

In Part 1, we presented the three primary types of data used in fish stock assessments—catch, abundance, and biology data. These data feed into mathematical models that represent the factors causing changes in harvested fish stocks.

In Part 2, we took a more detailed look at how stock assessment models work. The models produce estimates of the fishery management factors needed for managers to make informed decisions about how to best regulate a fishery. When possible, stock assessment models include information on ecosystem and environmental effects to improve the interpretation of historical information and the precision of forecasts.

Ecosystem Factors and Stock Assessments

- Factors other than fishing can have an influential role in determining the health and abundance of fish stocks. These factors are not only important to fish populations; by including them in the analysis of fishing effects, we can better interpret stock assessment results. Ecosystem factors such as species interactions, habitat, and large-scale climate patterns may be important.

- Food Web: All species within an ecosystem are connected to each other by the things that they eat, and the things that eat them. Tiny photosynthetic cells that capture carbon using energy from sunlight form the base of marine food webs, and provide the energy that ultimately powers top level carnivorous fish, marine mammals, and seabirds. The amount of primary productivity generated by plants and algae determines the number of fish that can be supported by an ecosystem. Because of these connections, the population dynamics of one species can affect the dynamics of many other species. A food web describes the connections between different species in an ecosystem through predator and prey relationships. Understanding these interactions can provide context for interpreting stock assessment results. Output from food web and predator-prey models can provide input to a single species assessment model, for example, the time series of natural mortality, providing improved stock assessment outputs.

- Competition and Other Species Interactions: Species interactions other than predator-prey relationships can also influence population dynamics. Because resources within marine ecosystems are limited, animals must compete for food and space. Competition within and between species, as well as symbiotic and other types of species relationships can all be important. In Part 2, we noted how the natural mortality rate of fish is an important piece of information in order to accurately estimate the level of fishing mortality. Because of competition, the total production of a system may be more limited than one might expect if each species is considered alone.

Why study food webs?

Studying a particular fish's prey and predators helps scientists understand how that fish is connected to other marine resources in the ocean. Fish, marine mammals, sea turtles, seabirds, and plankton all live in a balance known as the food web. Researching food web dynamics helps NOAA Fisheries scientists better understand the important factors to be considered in stock assessments. These stock assessments are used as tools for setting catch limits.

- **Habitat:** Healthy habitats sustain marine and coastal species, communities, and economies. Marine habitats may be altered in a number of ways, including through development, dredging, pollutants, or natural disasters. In turn, these alterations impact food sources, cover, refugia, and breeding grounds which are vital for reproduction, growth, metabolism, and other vital rates of marine species. Because habitat plays such a large role in structuring populations, understanding fish interactions with their habitat is important to stock assessment. One way that habitat information can improve stock assessments is by designing and analyzing fish abundance surveys according to habitat maps rather than simple geographic boundaries. Habitat quality and quantity may be assessed using habitat surveys—using multibeam sonars, echosounders, and underwater robots. These surveys map and document the physical, chemical, and biological system and help scientists understand complex interactions between fish and their habitats. Habitat features can be considered in these surveys to change the parameters and covariates affecting fish population dynamics. Habitat studies may also provide important information on species' vital rates, which are important inputs for stock assessments and can affect the accuracy and precision of assessment results.

- **Physical Environment:** In addition to physical habitat (e.g., bottom type), variability in ocean and climate patterns should also be taken into account when examining fish stocks. Many fish species have a relatively narrow range of temperature, chemical and other physical tolerances. Disruptions in the physical environment, due to climate or other perturbations, can impact natural stock behaviors such as spawning and migration. One effect of fluctuations in ocean conditions is on the numbers of young fish that survive from eggs to juveniles each year. For a fish stock like Pacific hake, the annual recruitment levels can be over 100 times different from year to year. Assessments can measure and track these changes in recruitment, but they cannot accurately forecast current and upcoming fluctuations without additional information. To improve forecasts, we need both better climate forecasts and better understanding of the effect of ocean climate on the factors that control fish recruitment. Incomplete understanding of the impact of climate and other physical parameters on populations can lead to a mismatch between seasonal fisheries regulations, migration patterns, and population distributions, leading to unintended impacts to fishery stocks.

What are ecosystem data?

Factors other than fishing can have an important role in determining the health and abundance of fish stocks. Ecosystem factors such as interactions among species in the marine food web, changes in marine coastal habitat, and constantly changing ocean environmental factors may be important. Examples of ecosystem data that may inform stock assessments include:

- Time series of physical or environmental data (e.g., ocean temperature, currents, etc.) that help scientists understand fluctuations in fish stocks and improve calibration of surveys that monitor stocks.
- Information on the effects of large-scale climate processes (e.g., El Niño) and climate change.
- Information on species habitat utilization, the quantity and quality of marine habitats, and the impacts of fishing on habitat.
- Predator-prey and other studies that provide more accurate values for important stock assessment parameters such as natural mortality.

A Holistic Approach

Traditionally, fish stock assessments have relied on direct measurement of fish stocks and catch to determine a stock's abundance and potential catch levels. This approach is effective for looking at present and historical conditions, but limited when trying to understand why changes occurred because it only accounts for the effects of fishing. This approach is also limited when trying to make accurate forecasts of sustainable catch levels because it does not account for changing ecosystem factors that could impact fish abundance.

The integrated analysis models described in Part 2 allow environmental and ecosystem factors to be included in a stock assessment model, which can help scientists better understand historical stock changes and improve forecasts. For example, research indicates that the annual catchability of several stocks of flatfish in the Bering Sea is affected by bottom water temperatures. For these species, colder water influences the timing of spawning migrations and also slows activity, making the fish less likely to be caught in survey trawls. Modeling the relationship between annual bottom temperatures and survey catchability for these species improves the fit of survey biomass estimates and reduces overall uncertainty in the model results. Ecosystem food web studies can also provide more accurate values for important fish assessment parameters, such as natural mortality. For example, several species of forage fishes like the Atlantic herring assessments have begun to include estimates of predation removals. Modeling the dynamics of Atlantic herring inclusive of predation has provided a more accurate accounting of what has been removed from the stock each year, and hence a more realistic understanding of how that stock behaves, consistent with scientific and fisher observations on the water.

More research is needed to determine which factors are most important to fish populations so these factors can be included in stock assessment models appropriately. It is clear that very often more than just catch can affect fish stocks. Fish stock assessment results often feed back into holistic ecosystem studies by providing long time series of information on historical fish abundance and productivity. NOAA Fisheries is committed to supporting science and research to move us toward effective ecosystem-based management. Developing tools and approaches for incorporating ecosystem factors will allow us to deal with the impacts of climate and other environmental change on our marine trust species.