Fisheries

Fisheries biologists use statistical models to transform disparate data, such as catch, research survey estimates, and the catch rates of fishermen into estimates of **abundance**, management regulations, and risk analyses. The result is an integrated assessment of a fish stock – a model of population dynamics that can be used to evaluate management decision. Such a statistical model combines data from many sources, using a variety of likelihoods, each representing a different piece of the data. The core statistical problem in fisheries is the estimation of parameters of such a model.

To conduct an assessment, fisheries biologists use some of the most complex statistical models available. Over 500 parameters can be estimated in nonlinear models using **maximum likelihood** or **Bayesian methods and modeling**. Such complex models are possible because vast amounts of data, in highly structured forms, are collected over a great number of years. Such large amounts of data are collected because of the high economic value and the political impact of the fishery.

One of the main tasks of an environmetrician working in the area is to separate out the data that are valuable, from the data that are not. Since data sources differ in their relative precision and accuracy, one difficulty is how to properly weight the likelihoods from these different sources of data in a reasonable manner. One method is to use the data to build the weights; e.g. weighted least squares (*see* **Least squares, general**). A disadvantage of this approach is that it may find a part of the data that is internally consistent, but biologically misleading.

The task of performing a stock assessment is complicated by the real or perceived incentives for fishermen to misinform collectors of statistical information about their activities (see [2] to understand the economic incentives of fishing). It is thus critical to have information independent of fishermen, e.g. statistically designed surveys of abundance (*see* **Creel surveys**; **Trawl surveys**). Determining the true behavior of fishermen is inherently difficult. Putting observers on boats is sometimes effective, but often fishermen change their behavior when observers are present. Unfortunately, these methods for securing accurate data are rarely sufficient to provide enough information to manage a fishery.

Surveying fish is much like surveying trees, except that you cannot see them and they move. Nevertheless, surveys of fish abundance, estimated independently of fishers, are key to fisheries management because catch per unit effort from commercial or recreational fishermen is not usually proportional to true abundance [4]. That is, as the abundance of fish declines, fishers are usually more efficient at capturing them.

A variety of surveys, that do not depend upon fishermen's behavior, are used to provide independent estimates of fish abundance, e.g. surveys with trawls, gillnets or acoustics. In all cases the efficiency of the survey gear usually changes from year to year, because there is either a change in the gear or the fish, e.g. water clarity may affect the ability of fish to avoid trawls. The **standard errors** estimated from standard survey design will thus almost always underestimate the true variability. Acoustic surveys are often worse because dispersed fish, fish close to the surface, or about to surface are difficult to detect. There are few attempts made to consider all the sources of estimation variability.

It is critical that such surveys be standardized, and that great effort be made to eliminate any changes in sampling efficiency of the gear. It is very difficult to calibrate surveys when a change occurs. For example, in trawl surveys, even 200 paired trawls may not be enough to for such a calibration because the survey catchability may change with environmental factors, e.g. depth, and not all sizes of all species may be present in large numbers when the calibration is carried out.

Surveys for fish populations differ from those used in the social sciences for several reasons, and any dogmatic following of design considerations may greatly reduce the utility of the surveys. For example, it is often best to randomize once when the survey begins (*see* **Randomization**), and to try to sample the same stations using the exact methods and locations year after year. Similarly, with acoustic surveys, attempts have been made to make transects 'independent' by only surveying in randomized transects (*see* **Line-transect sampling**). The gain from independence can be dealt with by spatial methods, and valuable survey time is not wasted.

The most common method for modeling the **population dynamics** of long-lived fish is by an age-structured model known as sequential population

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