# Appendix 4: Stock Assessment Principles and Terms

Much of the information in this report comes from the scientific analysis of fisheries data to develop stock assessments. **Stock assessment** is the process of collecting and analyzing demographic information about fish populations to describe the conditions or status of a fish stock. The result of a stock assessment is a report that often includes an estimation of the amount or abundance of the resource, an estimation of the rate at which it is being removed due to harvesting and other causes, and one or more reference levels of harvesting rate and/or abundance at which the stock can maintain itself in the long term. Stock assessments often contain short-term (1–5 years, typically) projections or prognoses for the stock under a number of different scenarios. This information on resource status is used by managers to determine what actions are needed to promote the best use of our living marine resources.

Stock assessment reports describe a range of life history characteristics for a given species, including age, growth, natural mortality, sexual maturity and reproduction, stock boundaries, diet preferences, habitat characteristics, species interactions, and environmental factors that may affect the species. Assessment reports also include descriptions of the fishery for a species, using information from both scientists and fishermen. Additionally, stock assessments describe the **assessment model**, or the collection of mathematical and statistical techniques that were used to perform the stock assessment.

Stock assessment analyses rely on various sources of information to estimate resource abundance and population trends. The principal information comes from the commercial and recreational fisheries (**fishery-dependent information**). For example, the quantity of fish caught and the individual sizes of the fish, their biological characteristics (e.g. age, maturity, and sex), and the ratio of fish caught to the time spent fishing (catch per unit of effort) are basic data for stock assessments. In addition, the National Marine Fisheries Service (NMFS) conducts resource surveys with specialized fishery research vessels or chartered fishing vessels (**fishery-independent information**). These surveys, often conducted in cooperation with state marine resource agencies, universities, the fishing industry, international scientific organizations, and fisheries agencies of other nations, produce estimates of resource abundance.

Resource surveys are conducted differently from commercial fishing. Commercial operations seek out the greatest aggregations of fish and target them to obtain the largest or most valuable catch. Fishery research vessels operate in a standardized manner, over a wide range of locations and within waters inhabited by the stocks, to provide unbiased population abundance and distribution indices year after year. The survey results are then used with commercial and recreational catch data to assess the resource base. The final critical data comes from studies on the basic biology of the animals themselves. Understanding the natural history of the harvested species and the other species with which they interact is crucial to understanding the population dynamics of living marine resources.

**Fish abundance** or population size can be expressed as either the number of fish or the total fish

weight (or biomass). Increases in the amount of fish are determined by body growth of individual fish in the population, and the addition or **recruitment** of new generations of young fish (i.e. **recruits**; recruits from the same year are said to comprise a **year-class** [or **cohort**]). Those gains must then be balanced against the proportion of the population removed by harvesting (called **fishing mortality**, ***F***) and other losses due, for example, to predation, starvation, or disease (called **natural mortality**, ***M***). In stock assessment work, removals of fish from the population are commonly expressed in terms of rates within a time period. The **fishing mortality rate** is a function of **fishing effort**, which includes the amount, type, and effectiveness of fishing gear and the time spent fishing. **Catch per unit of effort (CPUE)** is an index showing the ratio of a catch of fish, in numbers or in weight, and a standard measure of the fishing effort expended to catch them.

**Surplus production** (or production) is the total weight of fish that can be removed by fishing without changing the size of the population. It is calculated as the sum of the growth in weight of individuals in a population, plus the addition of biomass from new recruits, minus the biomass of animals lost to natural mortality.

The **production rate** is expressed as a proportion of the population size or biomass. The production rate can be highly variable owing to environmental fluctuations, predation, and other biological interactions with other populations. On average, production decreases at low and high population sizes, and biomass decreases as the amount of fishing effort increases. This means there is a relationship between average production and fishing effort. This relationship is known as the production function.

**Production functions** are the basis for certain important concepts used in this report: **maximum sustainable yield**, **current yield**, and **recent average yield**. In addition, the term **stock level** is employed as a biological reference for determining resource status relative to the biomass that would on average support the sustainable yield. Recent average yield also is reported in order to allow comparison of the current situation to the sustainable yield.

Many other **reference levels** are used as benchmarks for guiding management decisions. A number of these are expressed as fishing mortality rate levels that would achieve specific results from the average recruit to the fishery if the stock were subjected to fishing at those rates indefinitely. Some of these **benchmarks** are used to index potential fishery production, and others are used to index potential reproductive output. $\boldsymbol{F_{max}}$ is the fishing mortality rate that maximizes the yield obtained from the average recruit. **Growth overfishing** occurs over the range of fishing mortality, at which the losses in weight from total mortality exceed the gain in weight due to growth. This range is defined as beyond $F_{max}$. $\boldsymbol{F_{0.1}}$ is a rate that results in almost as much yield per recruit as $F_{max}$ does, but can be much lower—and thus more conservative—than $F_{max}$ (at $F_{0.1}$, only a 10% increase in yield per recruit occurs following an additional unit of fishing effort compared to the yield per recruit produced by the first unit of effort on the unexploited stock). Benchmarks used to measure reproductive potential usually express an amount of spawning output relative to the amount expected under no fishing. For example, $\boldsymbol{F_{20\%}}$ and $\boldsymbol{F_{30\%}}$ are the rates that would reduce spawning biomass per recruit to 20 or 30% of the unfished level, respectively. This percentage of the unfished level is also known as the **spawning potential ratio (SPR)**.

### Maximum Sustainable Yield (MSY)

**MSY** is the maximum long-term average yield that can be achieved through conscientious stewardship by controlling *F* through regulating fishing effort or total catch levels. MSY is a reference point for judging the potential of the resource. However, it is not necessarily the goal of fishery managers to always set the maximum yield. Other factors influence the choice of a management objective, such as socioeconomic considerations or conservation and ecosystem concerns for other marine life indirectly affected by fishery harvests. The methods of estimating MSY, and MSY itself, may be controversial. Nevertheless, NMFS scientists have used their best professional judgment to provide these figures as a gauge of long-term production potential whenever possible.

### Current Yield (CY)

**CY**, the potential catch that can be safely taken at the present time, depends on the current abundance of fish and population dynamics of the stock. It is usually estimated by applying the *F* associated with MSY (e.g. target fishing effort) to the current population size. This yield may be either greater than or less than MSY. CY is the amount of catch that will maintain the present population level (biomass) or, for overutilized stocks, stimulate a trend toward recovery to a population size that will produce the MSY. For stocks at high biomass levels, the CY may be larger than the MSY. In this circumstance a large fishery harvest would not be sustainable in the long run, but it would bring the stock down to the level supporting MSY.

### Recent Average Yield (RAY)

RAY is equivalent to recent average catch. Unless designated otherwise, RAY is the reported fishery landings averaged for the most recent 3-year period, 2004–06.

### Stock Level Relative to $B_{MSY}$

To further clarify resource status, stock level (i.e. abundance) in the most recent year available is compared with the biomass that on average would support the MSY harvest ($B_{MSY}$). This is expressed as being **below**, **near**, **above**, or **unknown** relative to $B_{MSY}$. In some cases, heavy fishing in the past reduced a stock to a low abundance, and even if the stock currently is harvested only lightly, it may take many years for it to rebuild.

### Harvest Rate

A stock's harvest rate compares the current harvest rate to a prescribed fishing mortality (catch) threshold defined in the stock's Fishery Management Plan (FMP). A stock is described as **overfishing** when the harvesting is occurring at a rate that is above the prescribed fishing mortality rate. A stock is **not overfishing** when harvesting is below that rate. A stock may also be classified as **undefined** if no fishing mortality threshold has been set in the FMP, or its harvest rate may be **unknown**.

### Stock Status

Stock status defines a stock's size relative to a prescribed biomass threshold defined in the stock's FMP. A stock is **overfished** when its stock size is below the prescribed biomass threshold, or **rebuilding** when its biomass has rebuilt to above the threshold level but not yet to the biomass target defined in the rebuilding plan. Stocks that have stock sizes above the prescribed biomass threshold are described as **not overfished**. Stocks may also be described as **undefined** if no prescribed biomass threshold has been set, or the current stock size may be **unknown**.

### Classification of Resource Status

Previous editions of *Our Living Oceans* have used utilization level[1] as a major factor in determining the status of a stock. However, this classification scheme did not always give a comprehensive picture of stock status or one that was consistent with legal classifications. The classification scheme used in *OLO 6th Edition* has been updated to be based on the requirements for status determination criteria listed in Fishery Management Plans (FMPs) and match the overfishing (Harvest Rate in *OLO*) and overfished (Stock Status in *OLO*) determinations that are listed in the *Annual Report to Congress on the Status of U.S. Fisheries*.

In 1989, NMFS published revised guidelines addressing National Standards 1 and 2 of the 1976 Magnuson Fishery Conservation and Management Act, as amended (1976 Act). Among other things, the intent of the guidelines was to prevent recruitment overfishing and to have a conservation standard for each fishery such that stocks were not driven to, or maintained at, the threshold of overfishing. The guidelines defined overfishing as a level or rate of fishing mortality that jeopardizes the long-term capacity of a stock or stock-complex to produce **maximum sustainable yield (MSY)** on a continuing basis. Each FMP was required to specify, to the maximum extent possible, an objec-

[1]A qualitative measure of the level of fishery use derived by comparing the present levels of fishing effort and stock abundance to those levels necessary to achieve the long-term potential yield (analogous to the MSY). Stocks were classified as underutilized, fully utilized, overutilized, or unknown.

tive and measurable definition of overfishing for each stock or stock complex covered by that FMP, and to provide an explanation of how the definition was determined and how it relates to reproductive potential. Overfishing could be expressed in terms of a minimum level of spawning biomass, maximum level or rate of fishing mortality, or other acceptable measurable standard. If data indicated that an overfished condition existed, a program must be established for rebuilding the stock over a period of time specified by the Fishery Management Councils (FMCs) and acceptable to the Secretary of Commerce.

Over the period 1989–96, NMFS and the FMCs used the 1989 guidelines as a basis for developing, refining, and evaluating definitions of overfishing based on recruitment overfishing thresholds. There was considerable variation in the overfishing definitions developed and accepted, due to the flexibility afforded by the guidelines. Subsequently, in late 1996, the Magnuson Act was reauthorized as the Magnuson–Stevens Fishery Conservation and Management Act (MSA) with several changes that required a rethinking of the basis for defining overfishing. In particular, the MSA required MSY itself to be the upper limit on the allowable amount or rate of fishing. NMFS responded by producing new guidelines that were finalized in mid 1998. The new guidelines required the specification of **status determination criteria**, which include both a maximum fishing mortality rate (beyond which **overfishing** is deemed to be occurring) and a minimum stock-size threshold (below which the stock is deemed to be **overfished**). Both criteria must be associated with MSY-based reference points. The MSA and the new guidelines have considerably reduced the amount of flexibility allowed in defining overfishing, and require a much greater degree of conservatism in the biological reference points used to delimit overfishing.

The MSA was reauthorized again in 2006 as the Magnuson–Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA). The reauthorization act gives NMFS even stronger laws that will enable it to stop overfishing and accelerate rebuilding of overfished stocks. One of the centerpieces of the new MSRA legislation is that it directs the regional FMC's to establish **annual catch limits (ACL's)** by 2010 for all stocks currently undergoing overfishing, and by 2011 for all other Federally managed stocks, setting a firm deadline to end overfishing in the United States.

### Economic value

In many of the fishery units, a dollar figure is given for the **ex-vessel revenue** generated by the commercial fishery on a given stock or group of stocks. Ex-vessel revenue is defined as the quantity of fish landed by commercial fishermen multiplied by the average price received by them at the first point of sale. As such, ex-vessel revenue captures the immediate value of the commercial harvest, but does not reflect multiplier effects of subsequent revenues generated by seafood processors, distributors, and retailers.

The estimate of economic value often takes both recreational and commercial catches and multiplies them by an average price to arrive at a baseline measure of economic worth among various user groups. It may underestimate those fisheries where there is a large recreational component. Nevertheless, the value serves as a useful gauge of relative potential revenues generated over many disparate stocks, fisheries, and regions.

### Marine Mammal Assessments

The same scientific principles apply to the population dynamics of these protected species, but the terminology of not overfished, rebuilding, and overfished does not apply. Instead, marine mammals are referred to as **depleted** when they are threatened or endangered under the Endangered Species Act (ESA) or when their population size is below their **optimum sustainable population (OSP)** level. Stocks are additionally classified as **strategic** when the level of direct human-caused mortality[2] exceeds the **potential biological removal (PBR)** level; when the stock is declining

[2]Total annual human-caused mortality is the total number of annual mortalities and serious injuries likely to result in death caused by humans and includes fisheries-caused mortality resulting from commercial fisheries, subsistence mortality resulting from subsistence hunting, and other removals such as ship strikes, strandings, orphaned animals collected for public display, mortalities associated with research activities, take by foreign countries, and mortalities associated with activities authorized through incidental take regulations.

and is likely to be listed as threatened under the ESA within the foreseeable future based on the best science available; or when the stock is listed as threatened or endangered under the ESA or depleted under the MMPA.

The Marine Mammal Protection Act (MMPA) defines OSP as the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of their habitat and the health of their ecosystem. For operational purposes, the U.S. Fish and Wildlife Service (USFWS)[3] and NMFS[4] have interpreted this definition to mean a population size falling within a range from the population level of a given species or stock which is the largest supportable within the ecosystem (carrying capacity) to the population level that results in maximum net productivity.

Potential biological removal is the maximum number of animals, not including natural mortalities, that may be removed from a stock while allowing that stock to reach or stay at its OSP level (50–100% of its carrying capacity). PBR is calculated using the minimum population estimate, the maximum net productivity rate, and the recovery factor. The **minimum population estimate ($N_{min}$)** is an estimate of the minimum number of animals in a stock, based on the best available scientific information on abundance and incorporating the precision and variability associated with such information, that provides reasonable assurance that the stock size is equal to or greater than the estimate. The **maximum net productivity rate ($R_{max}$)** is defined under the MMPA as the annual per-capita rate of increase in a stock resulting from additions due to reproduction, less losses due to mortality. The **recovery factor ($F_r$)** ranges between 0.1 and 1.0 and is used in calculating the PBR to compensate for endangered, threatened, depleted, or unknown stock status relative to OSP stocks.

Protected species of marine mammals may also be classified as **threatened** or **endangered** under the Endangered Species Act (ESA). A species is considered threatened if it is likely to become an endangered species in the foreseeable future. A species is considered endangered if it is in danger of extinction throughout a significant portion of its range.

[3]Implements programs and regulations for manatees, sea otters, polar bears, and walruses.
[4]Responsible for all non-USFWS-managed marine mammals, including whales, porpoises, dolphins, seals, and sea lions.