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** 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. Such 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 analyses rely on various sources of information to estimate resource abundance and population trends. The principal information comes from the commercial and recreational fisheries. For example, the quantity of fish caught, the individual sizes of the fish and 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. 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 on 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 ef-**

fort, 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. Intermittent high fishing effort is termed **pulse fishing.**

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: **long-term potential yield**, **current potential yield**, and **recent average yield**. In addition, the term **stock-level** is employed as a biological reference for determining resource status relative to the level which would on average support the long-term potential yield. Recent average yield also is reported in order to allow comparison of the current situation to long-term potential.

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. **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}. **$F_{0.1}$** 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, **$F_{20\%}$** and **$F_{30\%}$** 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)**.

Long-term potential yield (LTPY)

LTPY 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. LTPY 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 LTPY, and LTPY 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 potential yield (CPY)

CPY, the current potential catch that can be safely taken, depends on the current abundance of fish and population dynamics of the stock. It is usually estimated by applying the **F** associated with LTPY (e.g. target fishing effort) to the current population size. This yield may be either greater than or less than LTPY. CPY 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 LTPY. For stocks at high biomass levels, the CPY may be larger than the LTPY.

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 LTPY.

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 three-year period, 1995–97.

Stock-level relative to LTPY

To further clarify resource status, stock level (i.e. abundance) in the most recent year is compared with the level of abundance that on average would support the LTPY harvest. This is expressed as being **below**, **near**, **above** or **unknown** relative to the LTPY stock level. 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.

Status of resource utilization

In this report, a resource is classified as **underutilized**, **fully utilized**, **overutilized**, or **unknown** as a qualitative measure of the level of fishery use. This is derived by comparing the present levels of fishing effort and stock abundance to those levels necessary to achieve LTPY.

A fishery resource is defined as **fully utilized** when the amount of fishing effort used is about equal to the amount needed to achieve LTPY and where the resource is near its LTPY stock level. For fully utilized fisheries, the RAY and CPY are usually about equal. In most cases, LTPY and CPY are also about equal, but they may differ as a result of production variability.

A fishery resource is considered **overutilized** when more fishing effort is employed than is necessary to achieve LTPY. When RAY is greater than CPY, and CPY is less than LTPY, overutilization is indicated. If stock abundance is near the level that on average produces LTPY, RAY may be greater than LTPY for an overutilized stock, implying that recent landing levels cannot be sustained. If stock abundance is below the level associated with LTPY, RAY will likely be less than LTPY.

Additionally, it is possible for RAY, CPY, and LTPY to be about equal while the fishery resource is overutilized. This occurs when reducing fishing effort would have little effect on the amount of catch realized. In such cases, overutilization may not have an apparent adverse effect on production, but it further reduces the size of the population, it wastes effort and economic resources, and imposes other deleterious consequences (e.g. excessive bycatch and gear interactions).

A fishery resource is classified as **underutilized** when more fishing effort is required to achieve LTPY. This situation is generally indicated when RAY is less than CPY and CPY is greater than LTPY while stock level is above the reference level that on average produces LTPY. But there may be exceptions. For example, RAY may be held below CPY and LTPY by management to compensate for uncertainty in population estimates and ecosystem considerations.

Classification of stock and fishery status

The utilization level and stock-level relative to LTPY are the major factors NMFS considers for determining the status of a stock for *Our Living Oceans*, but they may not always give a complete picture or one that is consistent with legal classifications.

It is important to note the differences between this classification system and the classification systems based on requirements for overfishing definitions or status determination criteria in fishery management plans (FMP's). In 1989, NMFS published revised guidelines addressing National Standards 1 and 2 of the 1976 Magnuson Fishery Conservation and Management Act, as amended (Magnuson 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 objective 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 (FMC's) and acceptable to the Secretary of Commerce.

Over the period 1989–96, NMFS and the FMC's 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 (MSFCMA) with several changes that required a rethinking of the basis for defining overfishing. In particular, the MSFCMA 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 require 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 MSFCMA 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.

At the present time, most FMP's still contain definitions of overfishing that are based on the previous (more flexible) guidelines, although new definitions based on the new (less flexible and more conservative) guidelines are in the process of being developed and evaluated. Thus an analysis of stock status based on the overfishing definitions or status determination criteria contained in FMP's would not be consistent between stocks due to the widely differing degrees of conservatism embodied in the various definitions.

In summary, **overfished** (as defined in FMP's) is not equivalent to **overutilized** (as defined in OLO), and therefore, there will not be a one-to-one correspondence between the classifications. It should also be noted that NMFS's annual Report to Congress on the status of fisheries of the United States relies primarily on FMP definitions of overfishing and should therefore not be expected to give the same results for every stock as the OLO analysis. In the future, when all FMP's have incorporated status determination criteria based on the new guidelines, there may be greater correspondence between the FMP and OLO evaluations.

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 and Sea Turtle Assessments

The same scientific principles apply to the population dynamics of these protected species, but the terminology of underutilized, fully utilized, and overutilized does not apply. Instead, marine mammals are referred to as **depleted** when their population size is below the level of maximum net production. This is often referred to as their **optimum sustainable population (OSP)** level.

The Marine Mammal Protection Act (MMPA) defines OSP to mean "with respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." For operational purposes, NMFS and the U.S. Fish and Wildlife Service (USFWS) 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 to the population level that results in **maximum net productivity (MNP)**." Maximum net productivity is defined as "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction or growth less loses due to natural mortality."

Potential biological removal (PBR) 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 optimum sustainable population level (50–100% of its carrying capacity. **N_{min}** is a conservative estimate of abundance used to estimate PBR and provides reasonable assurance that the stock size is equal to or greater than the estimate.

Protected species of marine mammals and sea turtles may also be classified as **threatened** or **endangered** under the Endangered Species Act. A species is considered threatened if it is likely to become an endangered species in the foreseeable future throughout a significant portion of its range. A species is considered endangered if it is in danger of extinction throughout a significant portion of its range. In addition to some marine mammals and all sea turtles, several Pacific Coast salmon stocks are now listed as threatened or endangered.