Large-scale research programs such as the Global Ocean Ecosystem Dynamics (GLOBEC) Program have now been implemented throughout the world to assess the potential effects of global climate change on marine ecosystems, including impacts on resource species.

Collectively, the problems of overexploitation, habitat loss and degradation, alteration of ecosystem structure, and environmental change caused by human activities point to the need to fully consider humans as part of the ecosystem and not somehow apart and to manage accordingly. Wisely managed, fisheries can continue to meet important human needs for food resources from the sea and our obligations to future generations can be met.

## See also

**Coral Reef and Other Tropical Fisheries. Crustacean Fisheries. Demersal Species Fisheries. Marine Fishery Resources, Global State of. Molluskan Fisheries. Open Ocean Fisheries for Deep Water Species. Open Ocean Fisheries for Large Pelagic Species. Salmon Fisheries: Atlantic. Salmon Fisheries: Pacific. Seabirds and Fisheries Interaction. Small Pelagic Species Fisheries. Southern Ocean Fisheries.**

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# FISHERY MANAGEMENT

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The world's fisheries are significant from many perspectives: biological, economic, cultural, and political. Fisheries may be measured in terms of biological yield; economic returns and contributions to economic value, income and jobs; production of food; cultural dependence; recreation; relationship to the ecosystem and the environment; and domestic and international trade.

Total fisheries production is reviewed elsewhere in this volume (*see* **Marine Fishery Resources, Global State of**). The focus of this article is not on the fisheries themselves or the production from them, but rather the institutions of fisheries management. A broad definition of fisheries management will be used – a set of rules that govern who can fish and how fishing is conducted. Fishery management cuts across all the perspectives mentioned above and provides the bridge to human governance of fishery harvesting and processing.

An understanding of fisheries management is useful in interpreting trends in production, and changes in fleets, revenue, jobs, and income. More importantly, however it is largely the actions of fishery managers that will determine the dynamics and likely future of the world's fisheries.

## Introduction

Fisheries management is based on a number of goals. In general, managers seek to maximize long-term production from the fishery. Foremost among the formal concepts of management is the principle of maximum sustainable yield (MSY). MSY is derived from the fact that increasing application of effort will result in increasing catch (yield) up to a point at which additional effort will lead to decreased stock size and, subsequently, reductions in total yield.

It's not only important to maximize total sustainable production, however. Managers should also seek to maximize the total value of fisheries. This brings into consideration economic returns, costs, and profitability; social and cultural considerations such as jobs, income and preserving a way of life; and the value of the resource as food, the focus of recreational activity, etc. Maximizing the value of the fishery, however measured, is known as managing for optimum yield (OY). Again management systems around the world tend to manage for Optimum Yield, either directly or indirectly.

Beyond these concepts of maximization are goals associated with fairness and equity such as ensuring equal value to all users, preserving a historic fishery, preventing concentration of the fleet, and so forth.

It is clear that these goals and objectives can be in conflict and that much of fisheries management is devoted to preventing or, at least, minimizing such conflicts.

Why do we need fisheries management or, put another way, why do fishery management institutions exist? A century ago it was believed that fishery resources, particularly offshore marine fisheries, were inexhaustible – mankind's catch was small relative to the level of existing stocks and the stocks themselves were capable of production far in excess of these needs.

It is clear today that the world's fishery resources are not only exhaustible but also that, for many fisheries, current levels of fishing pressure are not sustainable. Stated more formally, for many of the world's fishery populations, demand at the current cost of production (taking into account the use of the best available technology) exceeds the rate of renewal of the fish population, thus resulting in overfishing (unsustainable fishing). As an example of this, the FAO considered the state of nearly 400 stocks as of 1996 and found that 73% were fully exploited or overexploited; 23% were overfished, depleted, or recovering (**Figure 1**).

Advances in technology, adoption of this technology, and the generally increasing demand for fishery products worldwide (mostly due to population growth but also due to gains in the standard of living and the perceived benefits of consuming fishery products) have contributed to this trend. Yet, fishery managers have been slow to recognize these changes and, even when recognized, management institutions have been slow to react. As a result the majority of the world's major stocks are fully exploited or overexploited and fisheries management is often perceived as having failed.

## Management Systems – Institutional Arrangements

Fishery management institutions have some limited sphere of influence. For example, a fishery management plan may manage a state or provincial fishery, a plan may deal with a region's fishery or fisheries, have national scope, and so forth. Moreover, there are many institutional arrangements that have jurisdiction beyond national boundaries, for example, the Northwest Atlantic Fishery Organization (NAFO), or the International Commission for the Conservation of Tuna (ICCAT).

Fishery management is directed toward maximizing the benefits of the production unit (fish stock) that is being managed. Since stock boundaries may transcend national boundaries, many new geopolitical complications arise. Thus it is important to design an institution which promotes compromise among diverse human interests and values. This can be difficult not only conceptually, but practically as well if different management bodies in different countries use different approaches, timing, systems, etc.

Since ultimately the goal is to manage a stock appropriately, it is possible to delegate some management elements to a more local scale, while

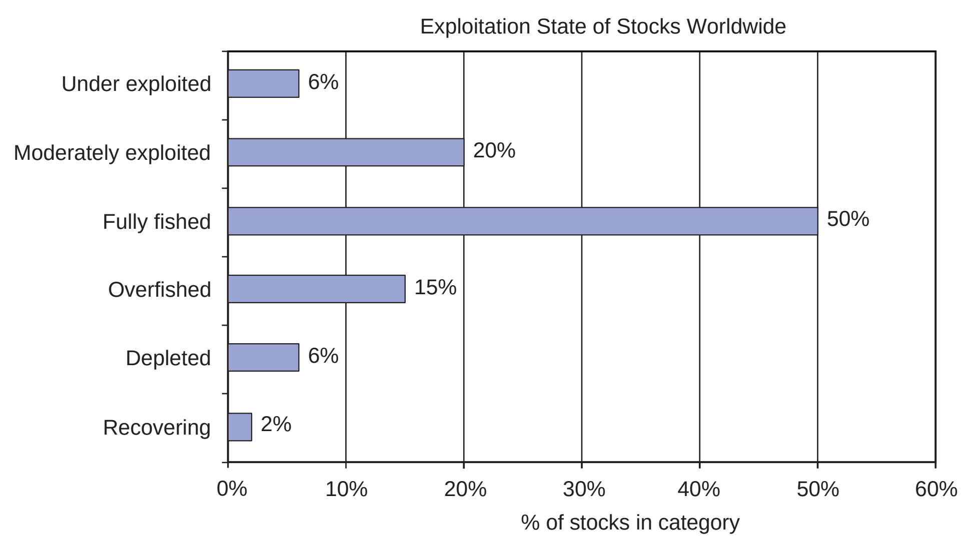


**Figure 1** Exploitation state for the world's stocks, 1996. (Adapted from Garcia and DeLeiva Moreno, 1999.)

insuring that the collective impact on the fishery resource is sustainable.

Management institutions-local, regional, national, or international-require supporting infrastructure. This includes research facilities and scientists to determine the current state of the managed stock or stocks, to assess how current management is interacting with these stocks and to provide advice on how future management will impact the sustainability of the managed species. The science that supports management is necessarily multidisciplinary in nature and includes biology, stock dynamics, oceanography and ecosystem considerations, economics, sociology, and institutional behavior. Beyond the science and its delivery to managers there must be in place data reporting and collections systems, and enforcement systems. Overlying all these systems is the management authority itself, consisting of one or more committees or panels responsible for making the decisions about the particulars of a management system.

If these roles are partitioned into science, reporting/monitoring, enforcement, and decision making, it can be seen that very different skills are appropriate to the various parts of the system. More importantly, stakeholders have different roles and responsibilities. Scientists need to be able to explain in a clear and concise manner the interaction between the fishery and the stock and the likely consequences of various management alternatives. Fishers need to report data in a timely and accurate manner, and data managers need to design data collection instruments that are effective and easy to comply with. Enforcement agencies need to have a dialog with managers to ensure that management plans are capable of being enforced and enforcement has to be applied uniformly, fairly, and consistently across all managed parties. In short, all the different players in the system need to articulate their concerns and the management authority needs to design a mechanism that allows a wide-ranging dialog while still providing for efficient decision making. This is a difficult task, made more problematic by some of the fundamental management difficulties discussed below.

Management institutions can be either formal, such as those established by law, or informal, such as nonlegally binding arrangements. The latter were common in villages or communities that influenced fishing practices of their members, helping to conserve fishery resources within their sphere of influence. Today, formal fishery management arrangements established in law are the norm. Such arrangements have become necessary because of the increases in efficiency and demand, and the increasing mobility of the population as traditional village or community level influences have broken down. It is now recognized that traditional informal management arrangements were insufficient to conserve fishery resources throughout their range. Thus there is a wide variety of national legislation and an elaborate international framework for managing fisheries.

The basis for international management authority flows from the United Nations Convention for the Law of the Sea (1982) (UNCLOS), which codified existing institutions and provided governance structure with respect to science, environmental control, and fishing and other commercial activities. UNCLOS extends jurisdiction to 200 miles, but also includes responsibilities for sustainable use of the resources under the control of each nation. To date some 132 states have become party to the convention. Notably signatories do not include the USA and Peru.

Beyond the fundamental agreement embodied in UNCLOS there have approved more recent agreements on straddling stocks and highly migratory fish stocks. Essentially these agreements provide common ground for dealing with the conservation of high seas stocks and for regional or subregional management authority for stocks which are transboundary in distribution. In addition, another agreement prohibits nations from allowing vessels to register in their country (known as flying a flag of convenience) in order to avoid enforcement of fishery management regulations of the country in which they fish.

In 1995 the Code of Conduct for Responsible Fishing was agreed to by the Committee on Fisheries of the Food and Agriculture Organization of the United Nations. This nonbinding Code of Conduct establishes norms for fishery management.

From a national perspective, extended jurisdiction to 200 miles for most countries (also flowing from the Law of the Sea) forms the cornerstone of fishery management authority. Within this authority are many approaches. For example, in the USA, legislation now called the Magnuson–Stevens Fishery Conservation Management Act (MSFCMA) was introduced in 1976. The MSFCMA provides for eight regional fishery management councils, representation from each of the region's states on the council, and a detailed protocol for public decision making. Councils develop Fishery Management Plans (FMPs) to be implemented by the US government so long as the plans achieve optimum yield and do not violate specified national standards. (The 10 national standards include maintaining optimum yield while preventing overfishing, scientific standards, management by stock unit, nondiscrimination among different states, efficiency, recognition of variation and contingencies, importance to fishing communities, minimization of bycatch, and the promotion of safety at sea.) The Act specifies the goal as obtaining optimum yield defined as MSY reduced by ecological, economic, and social factors. Although the MSFCMA has been amended several times since its inception, the principles of regional management, public debate, and decision making (technically advisory to the US Department of Commerce) utilizing technical committees (scientists), advisory panels (industry participants), and a decision-making body (the Council itself) have not changed.

Greater involvement of stakeholders in the fishery management process is becoming common. For example, Canada has a Fishery Resource Conservation Committee to advise on fishery management and the Australian Fisheries Management Authority forms groups of stakeholders to prepare fishery management plans.

The systems described, by and large, are in place in developed countries. In developing countries, biological complexity and a general lack of scientific and governmental infrastructure make fisheries management problematic. One solution may be to build on traditional community or village rights (which have been dismantled in many places) to develop more realistic options, perhaps along the lines of a participatory management approach.

## Management Systems – Controls

Since fishing involves the application of some effort to land a certain amount of fish, harvests can be controlled by either controlling effort or landings (or both). Effort controls may be direct, for example, limiting the total days spent fishing or may be indirect, controlling the amount of inputs used to produce a day of fishing. Thus, managers may limit net size, horsepower, hooks fished, and so forth. Input controls are based on the principle of regulated inefficiency. That is, if the manager restricts the technology that can be applied to catch fish, then the total harvest can be restricted so that it does not exceed a sustainable amount. Input controls are very commonly used in an attempt to overcome increases in total demand and improvements in technology which lead to increases in fishing power.

Note that input controls are usually gear specific. There may be minimum mesh size limits for trawls and gillnets, escape vent size limits for pots and traps, hook limits for longline or set gear, and so forth.

Unfortunately this general approach results in raising the total cost of fishing beyond what could be efficiently supplied. Additional inefficiencies arise when fishers invest in more unregulated inputs, seeking a competitive advantage (known as 'capital stuffing'). Direct effort controls, say by actively limiting days at sea, avoid the inefficiency of regulating individual inputs, but, unfortunately do not avoid the more general capital stuffing problem, as fishers are free to increase per day inputs in any number of dimensions. (Generally, however, such systems do not allow replacement of qualified vessels with new boats that are significantly larger, or have greatly increased horsepower.)

### Output Controls

The other fundamental management approach is to control output. Generally output controls take the form of limits on the landings of a species of fish, where the limits are commonly called quotas or Total Allowable Catches (TAC). Quotas generally apply to the annual output from a fishery, but it is not uncommon to have the annual quota further divided into seasonal quotas, region-specific quotas, or both. The ITQ management systems mentioned below also use overall output controls, and, in addition, limit the output of each individual fisher to that allocation implied by their quota share.

One difficulty in output control systems is distinguishing between catch and landings, i.e. accounting for discards. In principle, output limits are aligned with total mortality targets and thus relate to total catch (landings plus discards). In practice, especially if discards are poorly estimated or not estimated at all, only landings are counted and therefore total mortality may be underestimated.

### Time and Area Closures

Beyond restrictions on the inputs to catching fish or the total amount of fish caught, managers may also restrict when and where fishing can occur. This class of input management is known as time/area closure and is useful in protecting a stock in a particular place and time, for example, when the fish are aggregated for spawning. Alternatively, prohibiting fishing in certain areas for extended periods (perhaps year round) can provide a refuge for a core population of the regulated stock.

### Size Limits

It is not uncommon for managers to place restrictions on the minimum size of the animals taken in the fishery, and less commonly, the maximum size as well. This form of output control recognizes that the fishery is not completely selective and may capture fish that are too small (or too large when maximum size limits are in place). Minimum size limits attempt to eliminate mortality on juvenile fish as it is the survival and growth of these fish that provide for a sustainable fishery. Similarly, maximum size limits are intended to take advantage of the greater reproductive potential of larger more mature animals.

These size limits can lead to discarding. In practice, managers try to match gear restrictions with size limits so as to minimize waste. For example, in a trawl fishery, the minimum mesh size is usually set to allow some portion (e.g. 50%) of the fish below the minimum size to pass through the mesh. Here there is a tradeoff between the capture efficiency of the net and the desire to protect smaller fish. Similarly, managers can regulate hook size to enhance the probability that only larger fish will be captured, specify minimum mesh sizes in gillnets, etc.

To allow for enforcement of regulations on size limits, such limits are usually couched in terms of possession limits, for example, no possession of Atlantic cod that are less than 19″ (48 cm) in length.

### Prohibited Species Catch Limits

A special case of possession limit is the situation where managers do not want any individuals of a particular species captured. For example, in most of the world's fisheries it is illegal to capture large marine mammals such as whales or porpoises. If such an animal is caught the fisher is obligated to return it to the sea as quickly as possible with a minimum of harm. Generally speaking, such protections are applied to all marine mammals including seals, sea lions, and the like, and in some cases sea birds as well.

It also is possible that the possession of a species that may be targeted by other fisheries (perhaps under a different management jurisdiction) is not allowed. For example, in the bottom-fish fisheries of the North Pacific targeting primarily pollock, cod, and several species of flatfish, the possession of Pacific halibut, several species of crab, herring, and salmon is not allowed.

## Performance Issues

### Input versus Output Controls

On a worldwide basis most fisheries are not formally managed. For those that do utilize governance systems, management is, in general, based on input or output controls (or some combination of the two). There is a tendency for management to evolve from input to output controls and, perhaps, subsequently to harvest rights-based systems (see discussion below). Initially, managers tend to favor input controls, and in developing countries, management systems that do exist tend to take this form. Systems based on controlling input may be followed by an increasing reliance on output controls, because such systems do not explicitly impose inefficiencies, and more generally, can be more directly related to a sustainable level of fishing mortality and catch. Additionally, output limits such as quotas can easily be allocated between nations (for international fisheries where TAC management first became common), user groups, or individuals. While output controls do not explicitly impose inefficiencies, "quotas" do not necessarily solve the problem of the inefficiency in fisheries resulting from the race for the fish.

Output controls that result in shutdown of the fishery can lead to closures early in the season should the fishery harvest its allocation rapidly. Closure after a short season has considerable negative consequences including loss of jobs, income, social disruption, and the like. Managers can mitigate these effects by assigning quotas to seasons or areas, imposing trip limits, and so forth, but these measures tend to reduce the efficiency of the individual vessel.

Input controls, particularly direct controls on days fishing, avoid these problems by formally controlling fishing effort. Unfortunately, capital stuffing may be encouraged as boats attempt to increase their fishing power per unit of effort. Because of this, systems using input controls usually define a unit of fishing effort (e.g. a 50′ vessel with 1000 hp). It is therefore necessary that managers understand the link between a unit of effort, say a day at sea, and a day's catch as, ultimately, it is total fishing mortality (i.e. total output) that must be controlled. To the extent that fishers can add technology, labor, etc. to maximize production on a day at sea, management expectations on the conservation benefits of direct input controls may be too optimistic.

Progress toward attainment of input control limits are more difficult to monitor, requiring either a self-reporting or electronic monitoring system to determine if a vessel is actively fishing. A related difficulty in a system based entirely on input controls is that there may be no controls on output whatsoever. This means that if pre-season expectations on total mortality are not met then adjustments must be made in the next season.

In any case, unless fishing capacity or fishing power is somehow rationalized prior to and independent of the output or input controls, neither system will work effectively as fishers will either rapidly exhaust quotas or available days at sea and contribute to a protracted shutdown of the fishery. If these periods of inactivity are too long operations will not be able to cover their fixed costs and will go out of business.

### Allocation

To understand the effectiveness (or lack thereof) of management it is necessary to consider the fundamental principle in fisheries management: allocation. That is, beyond the particulars of the type of controls used to conserve the fishery resource, fisheries management is essentially a method to allocate a scarce resource (the fish) to a number of competing users. This means that the fisheries management process can be characterized as a debate about who are the winners and losers in terms of the opportunity to benefit from the extraction of the fishery resource. The allocation issue itself causes more and more layers of management to be added. For example, quotas might be established for particular areas, for particular gear groups (trawlers, longliners, etc.), for residents of a particular state or province, for vessels of different sizes (e.g. small trawlers, large trawlers) and so forth, resulting in a very Balkanized management system.

More to the point of trying to manage effectively, the allocation debate can easily overshadow the discussion on 'doing the right thing'. Thus, discussion on input versus output controls, open versus closed access versus access granted by harvest rights, may not occur as managers become pre-occupied with dividing up a limited pie among competing users instead of debating how to make the pie bigger.

### Competitive Allocation versus Rights-based Allocation

An overarching issue in fisheries management is the choice between rights-based allocations versus competitive allocations. Essentially, open access and limited access systems are competitive allocation systems and individual fishery quotas are a form of rights-based allocation.

Under rights-based management system, the holders of the rights have an incentive to conserve stocks and to provide the appropriate level of inputs for a given catch. And since fishers hold the rights to a certain portion of the catch and can land that amount at a time and place convenient to their operations, fishers operating under rights based systems tend to utilize the most efficient gear, time at sea, and so forth.

One such management system based on harvest rights is the Individual Fishery Quota system (IFQ) or Individual Transferable Quota system (ITQ). Management by individual quota has, for some nations, become the management system of choice (e.g., Iceland and New Zealand).

Rights-based systems may allocate output shares (IFQs) and those shares may be transferable among qualified participants (ITQs). Quotas may be freely transferable, or limited to certain quota holders (e.g. ITQ holders in a certain area). The total amount of shares held may be limited. Entitlements may be made to individuals, vessels, companies, communities, regions, etc. and transfers may be limited to like ownership categories. Allocations may be absolute (e.g. 10 metric tons of species A) or relative (e.g. one-tenth of 1% of the overall quota for species A).

In principle, management based on Individual Transferable Effort (e.g. days at sea) could also be utilized, although we are not aware of any systems that allow effort trading.

The principle of rights-based management can be simply stated. If the harvester has some assigned (and protected) rights to harvest a certain portion of a stock he will have every incentive to utilize inputs most efficiently, choose a vessel which is most appropriate for the way he wishes to prosecute a fishery, fish at a time and place that is both convenient and maximizes opportunities for maximizing catch or profit per unit of effort.

Granting such rights is controversial, however. Concerns include who is granted the initial privilege to fish and how does one deal with the 'windfall profit' provided to those who qualify (the quota holder's share can have significant economic value). Another concern is concentration in the fishery, since efficient operators can buy or lease rights from others and increase their scale of operations. Concentration can lead to a large boat fishery or a fishery with absentee owners. Finally, there is the issue of 'high grading' where fishers may discard less valuable animals (e.g. smaller fish) for which they hold quota so as to land the most revenue per pound of quota held.

### Effectiveness and Enforcement

Over time, given all the difficulties mentioned above, the management system can become very complex. Thus, it is not unusual to have a fundamental effort control system such as regulating days at sea, overlain with input restrictions, time/area closures, and the like. This can lead to very complex regulations that are poorly understood by fishers. More to the point, fishers dislike controls which limit their fishing opportunity and thus may not comply with regulations.

Given this, it becomes clear that a significant issue is the enforcement of regulations. Some measures are easy to enforce (e.g. a closed area) and some regulations are not (e.g. discard limits or reporting discards). This leads to two kinds of difficulties: the effectiveness of the regulations may be much less than intended or assumed, and enforcement agents may not be able to successfully prosecute violators.

## Problems and Issues

### Access

The issue of access, that is open versus limited versus rights-based access, as outlined above is the fundamental issue in management. Entry to fisheries has traditionally been open; newcomers, provided they had the necessary capital, could enter a fishery whenever they wished. Open access, however, leads to the race for the fish, and to the dissipation of rent (the returns beyond normal business profits that arise due to production from the renewable fishery resources). The 'race for fish' results from each individual fisher believing that another day at sea, more or better gear, electronics or other inputs will result in more revenue. This is, of course, true up to a point. However, as participation and effort increases, the actions of that fisher begin to negatively impact other fishers. These negative interactions increase external costs (called externalities by economists) via crowding, interference with the fishing operations of others or, more fundamentally, through depletion of the stock that others are trying to fish.

Failure to account for the externalities of fisheries production has been characterized as the 'tragedy of the commons', using the analogy of overgrazed public greens.

Given these well understood problems with open access, most developed fishing nations have begun to limit fisheries access to a set of individuals with an established history in the fishery (called limited access or limited entry). This barrier to new entry can, in principle, reduce stock externalities. In practice, however, many of the problems discussed above are still prevalent simply because the number of initial qualifiers exceeds what would be appropriate in a rationalized fishery (a fishery where available effort matches available supply). Further exacerbating the problem, qualified entrants have every incentive to increase their individual fishing power while ignoring the contribution of other fishers. Thus limited access, by itself, can be ineffective in matching fishing power or effort to sustainable levels of fishing.

### Ratchet Effect

Another reason for the general lack of success in managing fisheries, especially overexploited fisheries, is what has been characterized as the 'ratchet effect'. General scientific principles as well as guidance from the United Nations and the laws governing many national fisheries lead to a prescription of managing to produce the long-term equilibrium yield, usually the maximum sustainable yield (MSY). Thus, scientists provide advice on management goals that are based on long-term productivity considerations. In reality, fishery populations fluctuate in response to environmental conditions and interactions with other fish populations.

Dynamic, rather than stable, population levels can lead to a situation where managers and fishers tend to add capacity when stocks are stable or increasing, all the while attempting to reach a level of production equal to the maximum yield. However, should a downturn in the stock occur, managers are unable to quickly reduce fishing power, because of economic and political pressures to maintain jobs, income, and lifestyle. This feedback loop is very unattractive in that fishing pressure increases in good times but does not contract in bad times.

A similar problem occurs because there is pressure on managers to continue overfishing in the face of scientific uncertainty. This problem occurs because managers seek scientific consensus before taking action. In reality, the level of a fish population is determined via a complex set of interactions among the environment, other fish populations, and the fishery itself. Thus necessary information may be lacking, or timely information on a stock that is very dynamic may not be yet available. Again, the bias is uni-directional. In the face of uncertainty, managers tend to favor the most optimistic forecast and discount the least favorable.

### Discarding

Fisheries management institutions themselves can contribute to the 'management failure' when inefficient management rules lead to considerable biological and economic waste. One dimension of waste is fishery discarding and incidental catch or bycatch. Bycatch results from fishing operations that are not completely selective, that is, catch species other than those targeted. Often these fish are discarded, either because regulations require it, or because the product is not marketable. An example of regulatory discarding is the tossing overboard of fish below a minimum size limit.

Discarding of target species can also occur when the size or condition of the animal makes it less attractive to the market and the fisher discards so as to land the maximum value of product given restrictions on time fishing, hold space, or landing limits.

A similar problem is the discard resulting from regulatory landing limits or trip limits. Here, to limit overall fishing mortality or the mortality on a certain segment of the stock, managers restrict the landing of a species to a certain weight (or number) of fish per trip. Since fishery catches are often mixed and since some fish are more valuable than others, a vessel may discard large amounts of a nontargeted species or, alternatively over-harvest the target species, discarding the less valuable or smaller fish.

The waste apparent from discarding in a single species context can be greatly magnified when more than one species is being managed by trip limits. This is because the individual fishery trip limits now interact and the most constraining trip limit becomes the rule that controls total fisheries catch. Thus, considerable potential catch may be foregone. From the opposite perspective, waste may increase, as the mix of species taken in a fishery would only match the proportions implied by the set of all the various species' trip limits by chance (or if the trip limits were 'perfectly' estimated).

One further complication to the discarding problem is that adequate reporting systems may not be in place. Discards may not be reported, catch may be underestimated, and assessments based on a determination of total fishery mortality (landings and discards) may be inaccurate.

### Ecosystem Management

The difficulties facing managers due to some of the single-species issues discussed above become greatly complicated when managers attempt to control the harvest of several interacting stocks. Recently there has been a focus on what is called the ecosystem effects of fishing. Here, managers are being asked to not only manage single stocks and groups of stocks interacting in a multispecies fishery, but also to manage the entire ecosystem in which the fish occur; the fish, other nonfish populations, and the fishery habitat. Such a perspective is partly due to concerns about potentially environmentally destructive fishing practices and partly due to renewed interest in a holistic or ecosystem perspective for managing inter-related species. Unfortunately, managing for the ecosystem is much more complex than managing for single species maximum yield; data requirements are more demanding, scientific uncertainty is increased; and our ability to understand all the important biological and economic interactions is limited.

## Towards the Future

The problems discussed above and the linkages to decision making are shown in **Figure 2**. Unfortunately, the difficulties outlined are fairly endemic to fishery management and fairly intractable as well.

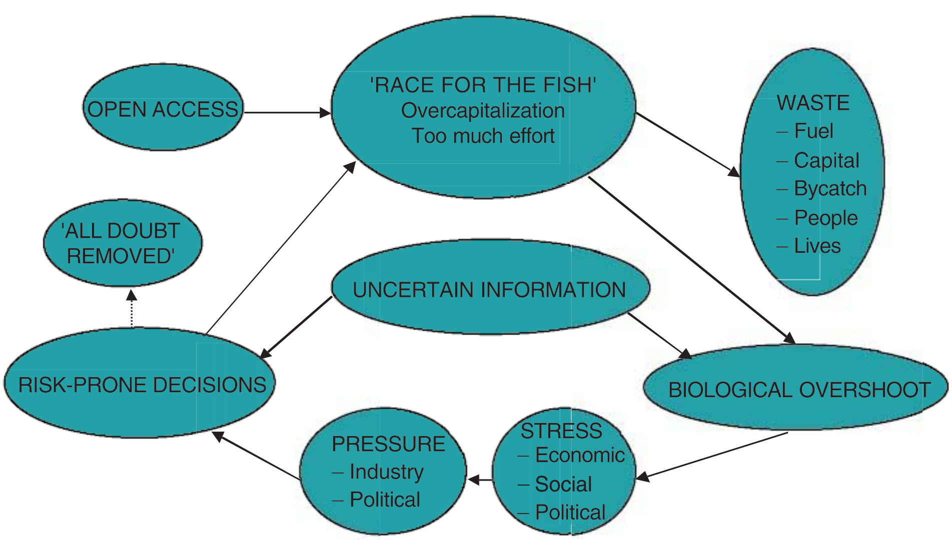


**Figure 2** A diagrammatic view of the fisheries management problem, showing the feedback mechanisms, which can lead to management failure. (Adapted with permission from Sissenwine and Rosenberg, 1993.)

Given this, the appropriate role for fisheries management is to put in place governance systems that reduce or eliminate discard and waste, promote efficiency, rationalize effort, and recognize management and scientific limitations.

Most important to effective management is the notion of controlled access and beyond this, rights-based access. Without mechanisms for efficiently controlling and allocating overall effort fishery management goals cannot be met. In this regard, incentive based systems such as ITQs or IFQs harvest systems, or less formal, but equally effective, community-based or regional control systems, offer the most promise.

### The Precautionary Approach

An emerging paradigm in fisheries management known as the precautionary approach is becoming the basis for fishery conservation systems worldwide. The precautionary approach is explicitly embodied in the Straddling Stocks and Highly Migratory Stocks agreement and the Code of Conduct mentioned above and is based on (but different from) the Precautionary Principle. The Principle implies an extreme reversal of the burden of proof in that it attempts to prevent irreversible damage to the environment by implementing strict conservation measures, even in the absence of evidence that environmental degradation is human caused. The precautionary approach also reverses the burden of proof but is designed to provide practical guidance for managers in the areas of fisheries management, fisheries research, and fisheries technology.

Formally, the definition offered by Restrepo *et al.* (1998) is:

> In fisheries, the Precautionary Approach is about applying judicious and responsible fisheries management practices, based on sound scientific research and analysis, proactively (to avoid or reverse overexploitation) rather than reactively (once all doubt has been removed and the resources are severely overexploited), to ensure the sustainability of fishery resources and associated ecosystems for the benefit of future as well as current generations.

Adoption of the precautionary approach as the overarching yardstick in developing management systems is important and has led to major changes in many of the developed nations' fisheries management strategies. For example, in the USA, the precautionary approach is the philosophy behind a number of important revisions to the MSFCMA which provided for management limits, risk-averse targets, specification of uncertainty, and the like.

In fact, the precautionary approach offers a road map for the future; a management perspective that can accommodate all the difficulties highlighted in this article. Providing for effective fisheries management on a worldwide (or even national) context is a daunting task but, with the adoption of an explicit risk-averse philosophy and participatory management practices and the rationalization of overall effort there is hope for success, rather than failure, in future management systems.

## See also

**Coral Reef and Other Tropical Fisheries. Crustacean Fisheries. Demersal Species Fisheries. Marine Fishery Resources, Global State of. Molluskan Fisheries. Open Ocean Fisheries for Deep Water Species. Open Ocean Fisheries for Large Pelagic Species. Salmon Fisheries: Atlantic. Salmon Fisheries: Pacific. Seabirds and Fisheries Interaction. Small Pelagic Species Fisheries. Southern Ocean Fisheries.**

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# FISHERY MANAGEMENT, HUMAN DIMENSION

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## Introduction

The human dimension is central, not peripheral, to fisheries management. In capture fisheries, the behavior of people can be managed, but not the behavior of fish. Consequently, being able to monitor human behavior and to enforce regulations is an important 'human dimension' of fisheries. Moreover, in all fisheries, management decisions affect individuals and social and cultural groups in different ways. Management decisions have social impacts and come about through political processes. Those processes and impacts are mediated by other aspects of human dimensions that come into play in fisheries management: cultural values and identity (of fishers, managers, scientists, consumers, and society at large); risk perception and behavior; and local, regional, and global demographic, economic, and political forces. We focus on legitimacy, a key aspect of politics. We show that the legitimacy of fisheries management institutions, and hence their success in achieving sustainable fisheries, depends on economic rationality, the use of science in decision-making, the fairness of the processes and decisions that come from it, and how various groups participate in the process.

Fish are an extremely important source of food and income. Worldwide, fish are the largest source of animal protein, even though they rank well behind terrestrial animals in Western countries. In addition, fishing is often an essential source of subsistence and income for people without other means of livelihood. This critical resource is under heavy pressure from increased exploitation and from environmental changes that reduce productivity. The Food and Agriculture Organization of the United Nations (FAO), the leading international agency dealing with fisheries management, believes that 69% of the known fish stocks need management urgently, and that a reduction of 30% is needed in global fishing effort.

Overfishing means removing fish from the water at a higher rate than that which would produce the greatest overall production of fish over time. If any large group of people is allowed to fish without restrictions, the result is likely to be decline in the productivity of the fish stock. The reason is simple: If there are no rules, and one person decides to leave a fish in the water to reproduce or grow bigger, someone else could catch that fish the next day. Neither the first person as an individual, nor the common good, benefits from the first person's restraint. The only one who benefits is the second person who catches the fish. In this situation, no one will voluntarily restrict his or her own fishing. It would be foolish.

Fisheries management is the process that creates and enforces the rules that are needed to prevent overfishing and help overfished stocks rebound. However, it is not about managing fish unless aquaculture is involved. In the case of capture fisheries, the focus of this article, fisheries management is entirely about managing the people who fish. Capture fisheries take many forms. Gigantic factory trawlers catch tonnes of pollock in the Bering Sea and then fillet and freeze the fish on board. This starts the fish on a path through the vast, global chain of processed foods. In the end they may be sold in a supermarket as part of a food product with nothing like 'pollock' appearing on the label. At the other extreme, millions of African and other farmers living near oceans, lakes, swamps, and rivers have small boats that they take out fishing when other tasks permit. These fish feed their families and are