ISBN 952-10-2817-3 (pdf)
ISSN 1235-4449

3.1. Sustainability in fisheries management

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INTRODUCTION

The history of fisheries management around the world is far from glorious. Many, or even most, attempts at marine capture fishery management have failed, and textbooks contain more examples of inefficient practices than successful management (Hilborn and Walters 1992, Ross 1997, Hall 1999, Charles 2001). World famous examples of failures to control overfishing include the collapses of the Peruvian anchoveta (*Engraulis ringens* Jenyns) fishery in the 1960s and 1970s, North Sea herring (*Clupea harengus* L.) stocks in the late 1960s, the Canadian Atlantic groundfish fishery (where cod *Gadus morhua* L. was the target species) in the early 1990s, and the Northwest Atlantic groundfish fishery (cod, haddock *Melanogrammus aeglefinus* (L.) , yellowtail flounder *Limanda ferruginea* (Storer)) in USA in mid 1990s. In all these cases natural resources have clearly not been exploited in biologically and socio-economically sustainable ways. Recently, researchers have reported that most commercial fisheries in the US are suffering from overfishing, inefficient harvesting, or both (Repetto 2001). Globally, Hall (1999) has estimated from the data of Food and Agriculture Organisation of the United Nations that over 35% of cephalopod stocks, 25% of demersal fish stocks, 5% of pelagic fish stocks and 25% of shellfish stocks are overfished.

In inland waters, overfishing problems are not as much of an issue as they are in marine fisheries, but rather environmental degradation represents the greatest challenge facing sustainable development (Arlinghaus et al. 2002). In Finnish lakes, at least the growth overfishing of fish stocks is not unusual. The widespread use of gill nets and the popularity of recreational rod fishing, both targeting predatory fishes such as pike (*Esox lucius* L.), pike-perch (*Sander lucioperca* (L.)), and brown trout (*Salmo trutta* L.), have led to skewed size-distributions and shortages of large, mature individuals. Growth overfishing occurs when fish are harvested at average sizes that are smaller than the sizes that would produce the maximum yield per recruit.

It is important to ask why attempts to manage fisheries sustainably have failed so often and to investigate the role of fisheries management in such cases. These key questions have been asked and analysed repeatedly by fisheries scientists and managers since the 1970s (e.g. Walters and Maguire 1996, Caddy 1999, MacGarvin 2001). According to Hilborn et al. (2001), "*Clearly, the uncertainties in fishery science and the difficulties of implementing management measures, particularly catch controls, are substantially greater than previously believed.*" In fishery systems, "*no one can be certain how much of the key ingredient is available in any given year, or what amount* *of product should be produced...*" (Charles 2001). It is thus widely understood that all decisions within fisheries management systems must be made under uncertain conditions (Charles 2001).

This chapter examines the questions asked above, and the answers given in fisheries literature, by looking at recent trends in strategic objectives and fisheries management practices. The evolution of simple single-species management into multi-species and ecosystem-based approaches with adaptive practices that follow precautionary principles demonstrates the growing complexity of sustainable fishery systems and the increasing requirements placed upon them.

This chapter focuses on the sustainability of capture fisheries. Capture fisheries include all the various forms of harvesting of aquatic organisms (including crabs, shrimps, mussels and seaweed etc., as well as fish) from both marine and freshwater environments, which together with the other important fisheries field, aquaculture, makes up total fisheries production. Aquaculture and stocking have in many countries been widely adopted alternatives in attempts to resolve the problems of capture fisheries. These practices can reduce the burden on over-exploited marine and freshwater stocks, while also satisfying the need for raw materials in the fishing industry, compensating for the effects of human-induced environmental disturbances on fish stocks, or meeting the local demand for intensive recreational fishing. Finding ways to manage wild fishery stocks and carrying out aquaculture together, while also considering the environmental consequences of both practices, is one of the major challenges facing stakeholders in fisheries (McVey 2001). This overall view of aquatic food production is beyond the scope of this book, apart from this brief introduction to the importance of sustainability in capture fisheries systems. Chapters 6.1. (Muje and Marjomäki 2005) and 3.2. (Karvonen et al. 2005) examine in greater detail the sustainability of Finland's inland fisheries systems and health problems facing fish in aquaculture.

COMPLEXITY OF FISHERIES MANAGEMENT SYSTEMS

Comparing the characteristics of marine and inland fisheries systems (Table 1) gives an insight into their complexity. This list also describes the continuing problems facing fisheries management in marine and inland environments. Conflicts concerning marine fisheries are typically international in scope, and concern much wider geographical areas than where inland fisheries are concerned. In inland fisheries, conflict and management are more based on bottom-up traditional local practices and the interests of local groups (Arlinghaus et al. 2002). Conflicts may include competition between commercial fisheries and recreational fishers, or the competition between fisheries and other uses of inland waters, such as the disposal of wastewater, electricity production, agriculture, and leisure activities. In Finland, traditionally managed fishing associations (Sipponen 1998) have been against various forms of the commercial fishing, such as trawling and seining, while favouring equipment typically used for fishing for house hold use and for recreational fishing, such as the nets, traps and angling and trolling tackle etc. commonly used by the shareholders of these associations. Thus, the management decisions taken regarding some small pelagic species (e.g. vendace *Coregonus albula* (L.)) have been very conservative, while for other species (e.g. bream Abramis *brama* (L.), pike-perch, brown trout) policies have been more exploitative.

Table 1. Selected differences between marine and inland fisheries systems in developed countries (compiled from Arlinghaus et al. 2002). This list is rough generalisation of traditional concepts of two systems and the variation in these features between real systems is high.

Characteristics	Marine fisheries	Inland fisheries
Access	Open	Restricted
Property rights	Less defined, common use	Well-defined, less common use
Structure	Global scale	Small scale, local systems
Free-riding	more likely	less likely
Reciprocal cooperation	less likely	more likely
Predominant form of fisheries	Commercial	Recreational
Benefits	Predominantly economic	Diverse use and nonuse benefits
Decision making practice	Institutional, political	Local owner driven, traditional
Management system	Reactive	Proactive (manipulating)
Interdependence between countries	High	Small
Effects of equipments on ecosystems	Extensive damage	Less damage
Overfishing	Unequivocal overfishing trends	Less overfishing tendencies
Physical and ecological diversity	Smaller	Great
Number of water bodies	Low	High
Connection between research and management	Interconnected units	Independent units
Fisheries research	Intensive research	Less research
Stocking	Not dominant tactical tool	Predominant tactical tool
Human impacts	Long-term influence	Short term influence
Diversity of user groups	Fishers dominant group	Diverse users, fishers less dominant
Economic importance	Important	Less important
Social priority	High	Low
Major concerns	Overfishing, regulation of fishing	Environmental degradation

Sustainability in Fisheries

Fisheries management theory on the whole is traditionally based on a rather biocentric philosophical viewpoint (Garcia and Grainger 1997) and focusing on physical output and aim to sustain fish stocks and harvests (Charles 2001). Modern perspectives on fishery management focus on whole systems and aim to produce healthy ecosystems and human systems (Charles 2001). Healthy aquatic ecosystems are able to produce high social and economic benefits while remaining ecologically sustainable at the same time (Arlinghaus et al. 2002). This kind of sustainability is called strong sustainability. It assumes that the various forms of capital (biological, ecological, economical, social) are not equivalent but complementary, and should each be conserved in their own right (Costanza and Daly 1992). Thus, strong sustainable development in fisheries includes reference to environmental quality, biological integrity, ecosystem health and biodiversity (Arlinghaus et al. 2002). In contrast, anthropocentric weak sustainability implies that natural, man-made, human and social forms of capital are perfect substitutes for each other (Arlinghaus et al. 2002). Under these conditions, for instance, if economic values are high enough it is acceptable that rates of exploitation may surpass the ecologically sustainable limits of the resources concerned.

How fisheries are managed

Fisheries management can be defined as the use of all types of information (ecological, economic, political and socio-cultural) in decision-making to achieve goals related to the use of fish resources (Krueger and Decker 1999). The use of all this information in the activities of specific fisheries involves developing suitable tactics and operational plans to guide fisheries in keeping with overall strategic fishery objectives and policy directions (Charles 2001). De la Mare (1998) has stated that the general objectives of fisheries management are to maximise benefits, to avoid deleterious changes to stocks and the environment, and to enable stability in the fishing industry. These factors cannot all be simultaneously maximised, and some compromises between them are required.

Fisheries management consists of the following elements (cf. Caddy 1999, De la Mare 1998, Charles 2001):

1) assessment (i.e. determining stock sizes, the extent of fishing efforts and fishing catches and recognising alternative management objectives);
2) decision-making (i.e. choice of strategic objectives);
3) selection of harvest strategies and tactics;
4) implementation of a chosen set of management tactics and measures; and
5) controls over implementation.

In capture fisheries management, the extent of fishing efforts will be adjusted to produce a sustainable state, i.e. the maximum biomass, maximum fishing employment, maximum sustainable yield, maximum economic yield or optimum sustainable yield (see next chapter). These strategic fishery objectives are implemented by balancing the multiple objectives of society (Charles 2001). The harvesting strategy can be decided after setting the objectives, so that all the tactical and operational aspects (implementation and control) correspond to the objectives set out in the strategic management process and are compatible with the strategic management policy choices. Unfortunately, these objectives often remain unclear or cannot be decided on, so unequivocal tactical plans and measures are also impossible to realise. This is typical in inland fisheries systems, where traditional owner-driven management is based on the experience of decision-makers, and the objectives are effectively traditions, rather than the unambiguous goals that can be set through co-operative planning and the detailed comparison of alternatives.

Harvesting strategies can be formulated by local decision-makers with the active participation of fishers and processors. The simplest strategies are stock-size-dependent strategies e.g. constant-stock-size, constant-exploitation-rate and constant-catch

Photo: Juha Karjalainen

Fig. 1. Modern gear make inland fisheries efficient: fish removal in Lake Pohjalampi, Eastern Finland in 1995.

strategies (Hilborn and Walters 1992). The central part of this process is the comparison between the outcomes of different strategies.

A detailed set of annual regulations, or harvesting tactics, are needed to implement a chosen strategy. Harvesting tactics are implemented through management measures which can be divided into three categories (Charles 2001):

1) input controls regulating the fishing effort, e.g. the number of boats, vessel capacity, fishing intensity and the permissible time or fishing area per boat;
2) output controls to determine the permissible catch, e.g. the total allowable catch (TAC) within a specific fishing area, quotas for individual fishers or a fishing community, or legal limits on the sizes of fish that can be caught (often the lowest permissible size); and
3) technical measures setting limits on where, when and how fishers may fish. Limitations on fishing tackle (e.g. mesh or hook size), closed areas (e.g. nursery grounds and ecologically based marine protected areas) and closed seasons (e.g. spawning closure) are the most commonly used technical measures.

Most fisheries employ more than one of the above tactical tools to reach their strategic goals (Hilborn and Walters 1992). Regulations and catches are traditionally controlled through the use of logbooks, with landings also checked in port and by sea patrols (Caddy 1999). Although new technology such as monitoring, control and surveillance systems using satellite tracking and telemetry has made it easier for fisheries managers to detect illegal or misreported catches, controls on fisheries still depend heavily on voluntary reporting, and thus on co-operation and trust between managers and fishers.

SOME STEPS ON THE WAY TOWARDS SUSTAINABLE FISHERIES

This chapter summarises the gradual evolution of the fisheries management from the concept of harvesting an independent single species obeying deterministic laws of science, towards the holistic management of ecosystems under conditions of uncertainty. The trends in strategic objectives, increasing awareness of the uncertainties in fisheries systems and developments in management practices are also introduced.

Objectives: from Maximum Sustainable Yield to Optimal Sustainable Yield

Where the objectives of fisheries management are concerned, the concept of Maximum Sustainable Yield (MSY) was dominant from the 1930s to the 1970s. The basic idea behind MSY will only be summarised here (for more detailed descriptions, see Graham 1935, Schaefer 1954, 1957, Beverton and Holt 1957). Any species will produce a harvestable surplus on an annual basis. If catches do not exceed this surplus, stocks can go on being exploited continuously and still remain at equilibrium. The harvestable surplus production (net production) depends on the stock size. No surplus will be produced by unharvested stocks in virgin state, or by zero stocks. The surplus generated per individual is higher where total stocks are lower, due to compensatory processes in mortality, growth and reproduction. The surplus is maximised where the product of the stock size and the individual rate of production is maximised (Fig. 2). To maximise the sustainable yield, those responsible for assessment only need to determine the fishing mortality (mortality of fish induced by fishing and producing catch) and hence the stock size that maximises production. Under the simplest assumptions of logistic growth this maximum is located at the midpoint between zero and maximum stock. Various other functional forms have also been applied to different stocks. A range of harvesting strategies has also been applied to help realise the objective MSY so that the stock remains fixed at its most productive level. Where more dynamic stocks are concerned, instead of constancy, the total allowable catch (TAC) could be set annually to keep stocks as close as possible to their optimum level.

Despite of the solid theoretical background for production rates, and simplicity of the target itself, the application of the sustainable yield target led to catastrophic consequences for various reasons. One of these reasons lay in assessment procedures. The estimates for MSY and annual yield and effort targets contain uncertainties (see below for sources). If the MSY or the TAC is over-estimated and taken from a randomly varying stock, this will rapidly lead to stock collapse (Beddington and May 1977). Other problems in implementing quotas relate to the following factors (Beverton 1998):

1) many fisheries catch more than one species;
2) it is difficult to forecast incoming recruitment accurately;
3) landing limits have been widely disregarded;
4) underreporting has degraded the database; and
5) confidence between fishers and scientists has been destroyed.

Controlling catches is therefore not an effective way of controlling fishing mortality. From the biological point of view, the concept of MSY is not sufficient either, because it does not account for the effect of fishing on the age-structure of the catch, the genetic properties of population, the presence of sub-populations with varying productivity, and problems related to multi-species fisheries (Larkin 1977).

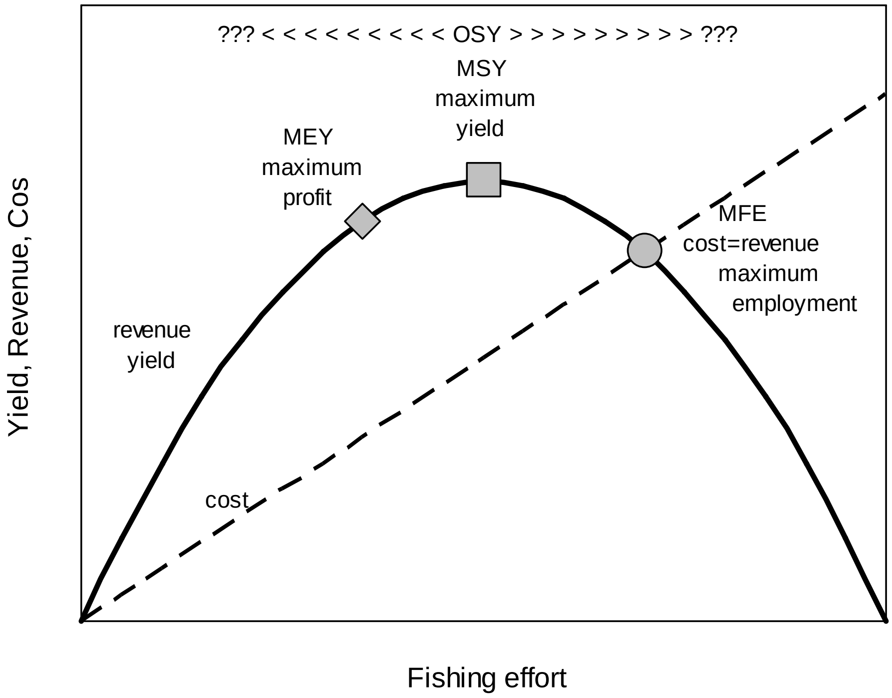

Fig. 2. A Gordon-Schaefer diagram showing annual sustainable yield or revenue and operating costs in relation to the annual fishing efforts (as shown on the horizontal axis). MEY = maximum economic yield, MSY = maximum sustainable yield, MFE = maximum fishing employment, OSY = optimal sustainable yield.

From the yield-stability point of view, which is valuable for fishers and the industry as a whole, MSY involves greater elements of potential instability than are characteristic of unexploited stocks. Consequently, fishing mortality which produces MSY has been transformed from target reference point to limit reference point representing the highest limit of exploitation, and giving way to lower level targets (e.g. Rose & Cowan 2003)**.**

The simplistic maximisation of the production of fish for human consumption within MSY was challenged from economic and social viewpoints. When economic theory on production models was applied, with the costs of fishing taken into account (Gordon 1954, see Anderson 1986 for more thorough analysis), it became evident that the fishing effort and yield that maximise the total profit obtained from a fishery were often lower than those for MSY (Fig. 2). Since commercial fishing is primarily a means for gaining economic wealth, the profit-maximising Maximum Economic Yield (MEY) would thus be a preferable target for sustainable fisheries. The establishment of any further, unregulated, free-access fisheries would lead to increases in mortality until no profit would be obtained. Despite the wide understanding of the concept of MEY, many fisheries have been pushed to this point, and even beyond, due to the inability to control increases in fishing mortality and continuing governmental subsidy programs even for fisheries that are only marginally profitable.

After the biologists and economists had pinpointed their respective theoretical optimum points along the fish production curve, social scientists began to express their own opinion. By the 1970s it was pointed out that just as fishing serves economic ends, economics serve social ends, and therefore the objective should be to obtain the maximum sustained yield of social benefits (Larkin 1977). The new concept of the

Optimum Sustainable Yield (OSY) combined biological, economic, social and political values (Roedel 1975). One welcome feature of the OSY was that it could also incorporate such considerations as the non-monetary values of recreational fisheries, the conservational value of fish stocks, the sustainability of fishing communities, and ecosystem integrity. OSY has consequently been criticised as being difficult to define and agree on, and therefore open to abuse. This led Larkin (1977) to the following unanswerable criticism: "*sometimes optimum yield will be almost zero; other times it will be MSY except when it is more***;** *still other times it will be maximum net economic yield; and for some species it will be all they can stand without becoming extinct*".

This is the current situation, where having started from the simple management objective of MSY, a new objective has emerged for maximising the sum of many different utility curves from different sectors of society, each possessing different weighting factors in the sum total to be negotiated by the various stakeholders. The simple biological maximisation of yield has turned into a kind of fuzzy social politics. The idea of OSY has thus greatly complicated fisheries management. Yet, these ideas are all perfectly relevant here, considering the ultimate purpose of fisheries: to produce sustainable social and economic benefits for society while keeping aquatic ecosystem healthy.

From false determinism to accepting uncertainty and managing risk

One of the reasons for failures in fisheries management in the past was that fundamental uncertainties in fisheries science were not understood. It is now widely realised that such uncertainties and the consequent difficulties in implementing fisheries management measures are substantially greater than previously believed, and that fishery management consists of a problem in decision-making under conditions of uncertainty (Hilborn et al. 2001). According to the Food and Agriculture Organisation of the United Nations (FAO 1995), this uncertainty concerns "*The incompleteness of knowledge about the state or processes (past, present, and future) of nature*". Several types of uncertainty are involved here (for more details and references see Francis and Shotton 1997).

1) Process uncertainty concerns the underlying stochasticity in population dynamics, such as the variability in recruitment. This type of uncertainty arises from natural variability, rather than any error.
2) Observation uncertainty arises in the process of data collection, through measurement and sampling error, inadequate data collection systems and misreporting.
3) Model uncertainty arises from the lack of complete information on the population and community dynamics of the system. The term "model" refers to the conceptual model that fisheries scientists and managers use as an aid in making inferences and decisions about fish populations and fisheries.
4) Estimation uncertainty relates to the process of parameter estimation, and derives from some or all of the three types of uncertainty described above.
5) Implementation uncertainty concerns the extent to which management policies will be successfully implemented in practice.
6) Institutional uncertainty arises from problems associated with the interaction of individuals and groups (scientists, economists, fishers, etc.) within the management process. Importantly, O'Boyle (1993) suggested that this could exceed "quantifiable" sources of uncertainty in stock assessments. Thus, this sort

of uncertainty may have been in many cases the most important reason for poor managemental success.

The importance of uncertainty for management is that a lack of knowledge inevitably causes risk. Risk can be defined simply as the probability of something undesirable happening (Francis and Shotton 1997). Expressed as a probability, risk is thus a quantitative measure. Dealing with risk has two stages: risk assessment and risk management (Pearce and Walters 1992, Lane and Stephenson 1997).

Risk assessment deals with the formulation of advice for fisheries managers, while risk management focuses on the ways managers use this advice to make decisions, to devise and implement management policies, strategies, and tactics that reduce the risks both to fish stocks, and, as emphasised by Hilborn et al. (2001), to the communities exploiting them. Risk assessment overcomes some former difficulties in management by showing the likely consequences of following each optional strategy, rather than presenting a “best” option from a range of strategies. Risk assessment also acknowledges and incorporates uncertainty by presenting the results in the form of probabilities, or expected values. Furthermore, it attempts to give to those responsible for making decisions the information they need (Francis and Shotton 1997).

Various aspects of risk management have been increasingly suggested and applied in fisheries management. These aspects include:

1) the construction of “robust” procedures that are expected to perform reasonably well, with tolerable risk, even when the assumptions on which they were based prove to be false (Kirkwood 1997);
2) risk sharing by diversification among fishers to exploit a wide range of species and high mobility of labour and capital;
3) insurance in monetary terms or using marine reserves as an insurance against the failure of conventional methods of management; and
4) community-based management in which the community has user privileges for some resources and thus the entire community shares the risk. (Hilborn et al. 2001).

Attitudes towards risk can vary considerably between different groups of actors in the management system. The general public has become increasingly aware of the extent to which industrial activities may have major impacts on the environment. This has led to greater public influence in fisheries management decisions, and pressure on fisheries agencies to adopt low-risk policies (Walters and Pearce 1996). One of the manifestations of public desire for more caution in fisheries management is the promotion of the precautionary approach, which has had the effect of focusing the attention of fisheries scientists and managers on questions of risk (Francis and Shotton 1997). The precautionary approach has been adopted as one of the general principles to be followed in a code of conduct for responsible fisheries (FAO 1995). The main points of the precautionary principle have been set out as follows (FAO 1996):

“*The precautionary approach involves the application of prudent foresight. Taking account of the uncertainties in fisheries systems and the need to take action with incomplete knowledge, it requires* inter alia*: a) consideration of the needs of future generations and avoidance of changes that are not potentially reverse; b) prior identification of undesirable outcomes and of measures that will avoid them or correct them promptly; c) that any necessary corrective measures are initiated without delay; d) that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource; e) that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource; f) all fishing activities must have* *prior management authorization and be subject to periodic review; g) an established legal and institutional framework for fisheries management, within which management plans that implement the above points are instituted for each fishery; and h) appropriate placement of burden of proof by adhering to the requirements above.*”

Unfortunately, there is little consensus on how the precautionary approach should be applied in managing overcapitalised marine fisheries, and new methods for risk assessment are urgently needed (Weeks and Berkeley 2000). The principal problem now is to find practices to allow fishers to turn theory into practice, against a backdrop of short-term economic pressures (MacGarvin 2001).

It has been argued by Hilborn et al. (2001) that applying the precautionary approach to the protection of the resources may lead to unnecessary fishery closures, causing irreversible damage to fishing communities. They suggested widening the scope of the approach so that it should explicitly include the protection of fishing communities, by implementing risk assessment and management to evaluate and implement management measures that will reduce the risks facing fishing communities. This implies sustainable use, consistent with their view that the goal of fisheries management is not to conserve fish stocks merely for the sake of conservation, but rather to achieve long-term sustainability in both the fishery resource and the fishing communities.

From a single species in a black box to ecosystem based management

As stated above, fisheries management originally concentrated on single species harvesting. Single species management was based on the simplified “black box” assumption that the dynamics of any species would not be significantly affected by any other changes in the fish community or the wider environmental context. Later, however, considerations at the multi-species community and ecosystem level gradually had to be taken into account in both assessment and management. One reason for this wider scope was that fishing targeting one species also caught considerable numbers of fish of other species, as by-catch, thereby interfering with the management of the by-catch species’ stocks. Similarly, it was realised that the dynamics of a species in the ecological community also affected the production of other species due to links such as competition and predation. Consequently, the need to reduce uncertainty in assessment led to the incorporation of community dynamics and the effects of several fishing fleets into models. Various multi-species approach methods and models have been developed since the 1970s.

Modern perspectives on fisheries management increasingly emphasise that although the primary goal of sustainable fisheries is to preserve the long-term viability of the target species, even harvest levels considered sustainable can have wider impacts on ecosystems. In order to protect ecosystems in future, broader and more integrated scientific analyses will need to focus simultaneously on many species (Zabel et al. 2003). Modern fisheries management focuses on whole systems, and aims to sustain both healthy ecosystems and viable socio-economic systems (Charles 2001). According to Arlinghaus et al. (2002), healthy aquatic ecosystems are able to produce high social and economic benefits while remaining ecologically sustainable. This claim is easy to accept but difficult to reach. In every case, decision makers must find a balance between different choices and values, considering economic values, employment, the health of the fishing industry and fishing communities, as well as the long-term condition of fish resources, especially in marine fisheries. Threats to inland fisheries mainly originate from outside the fisheries sector, so sustainable inland fisheries management systems have to be considered in holistic management as integrated parts of specific aquatic ecosystems or river systems (Arlinghaus et al. 2002).

SEARCHING FOR NEW PERSPECTIVES

Understanding management as a system

The failures of fisheries management may result from the widespread failure to consider the management of fisheries as a whole system (De la Mare 1998). In many cases, there seems to be an inadequate interface between fisheries science and decision-making, particularly concerning how decision-makers use any available quantified knowledge on factors of uncertainty. To improve communication and management, a management-oriented paradigm (MOP) has been suggested which crosses the traditional boundaries between scientific, economic and policy research on fisheries. MOP involves formulating management objectives that are measurable, specifying sets of rules for decision-making, and specifying the data and methods to be used, all in such a way that the properties of the resultant system can be evaluated in advance. The prospective evaluation of management systems involves the use of computer simulations and the development of performance measures that demonstrate the likely success of management systems in meeting its objectives (De la Mare 1998).

Multiple criteria decision-making

Incorporating uncertainty and its consequences into the scope of fisheries management has on one hand helped us to see some of the major limitations that reduce our ability to observe and manage systems, and this should help us avoid making or at least recognise the risks of wrong decisions. All this uncertainty seems to complicate management issues by requiring complex tools for multiple criteria decision-making. However, as Ludwig et al. (1993) encouragingly emphasise, most principles of decision-making under uncertainty are simply common sense. We must consider a variety of plausible hypotheses about the world; consider a variety of possible strategies; favour actions that stand up to uncertainties; hedge our bets; favour actions that will be informative; probe and experiment; monitor results; update assessments and modify policy accordingly; and favour actions that are reversible. In every case, decisions should only be made if the facts are clear enough, and allow the alternatives to be simplified. The importance of these considerations should be stressed in the messages sent by decision-makers to fisheries scientists. In many cases, all the necessary information is actually available, but decision-makers are unable to make difficult decisions, and all too often inefficient compromises fail to prevent collapses and protect fish stocks. This is the message fisheries scientists must send to the decision-makers.

New, holistic risk-averse approaches

The technical development in integrated and Bayesian assessment methodologies of risk assessment makes possible to calculate and evaluate the probabilistic consequences of various combinations of assessment assumptions, data treatments and management measures (Hilborn et al. 2001). This methodological basis should be adopted, incorporating the precautionary approach to reduce the risks facing fishing communities (Hilborn et al. 2001). On the other hand, the uncertainty of the biological basis for fisheries management can be greatly reduced by examining data sets from many separate populations, and then combining the results in meta-analysis, using various statistical methods (Myers & Mertz 1998). New risk-averse management approaches must be developed that can withstand uncertainties concerning both the effects of fishing on the ecosystem, and the effects of regulations (Weeks and Berkeley 2000). However, as Hilborn et al. (2001) have pointed out, risks may be assessed and decreased but not avoided altogether, since the great uncertainties surrounding management decisions make risk unavoidable. Hilborn et al. (2001) nevertheless conclude that where fisheries stakeholders succeed in maintaining stable fishing communities, it is possible to begin to manage risks.

Common knowledge shared between various interest groups

Holistic approaches - multiobjective, ecosystem-based, negotiated by various interest groups and directed by multicriteria decision-making - are sensitive to conflicts which are often driven by traditional attitudes, insufficient knowledge and lack of communication between the participants. A major advantage of successful co-management (sharing of decision making and management between government, owners and other user groups) is that all participants in the process are able to educate themselves and share the collective information pool. Scientific, local and administrative information (see also chapter 6.1., Muje and Marjomäki 2005) must be jointly processed and intercalibrated. This information processing should be active but it may also happen passively and these alternative processes may again lead to conflicts.

In any case, the supportive process should strengthen the trust between the interest groups. Only information which is widely accepted among participants can be the base of sustainable fisheries community. If the community determines and decides to set the OSY as an objective it can be implemented successfully only if most of the interest groups will agree upon this goal. Sustainable management must be based on scientific understanding of the whole fisheries system but this comprehensive view must then be communicated in such a way that most stakeholders understand and acknowledge this knowledge and its consequences.

In Finnish inland fisheries the joint knowledge includes *inter alia*:

1) scientific data and its interpretation by fisheries scientist, ecologists, limnologist etc.;
2) the experiences and observations of professional and recreational fishers;
3) the experiences and observations of the stakeholders in the associations of owners of fishing rights;
4) the knowledge of fisheries managers in local and central government;
5) the knowledge of local advisor organizations; and
6) the experience of lakeside residents.

Why fisheries management has failed

Uncertainties behind estimations of stock sizes, stock assessment models and the implementation of management measures have resulted in unsuccessful management of fisheries in many marine stocks. Still, often serious management failures are primarily because the decision makers have chosen not to follow scientific advice. Furthermore, the high economic and employment significance of fisheries on the local level, and the fact that many decision-makers have direct ties to the fishing industry has complicated the management (Ross 1997).

Meanwhile, traditional exploitation conceptions have promoted the exploitative use of fish stocks. The main principles involved here are:

1) fishing is expected to increase the surplus production of a fish population by compensatory mechanisms (Graham 1935); and
2) fishing may reduce the annual variations in stocks of small-sized, schooling fish species such as clupeids and coregonids.

These conceptions have led to the setting of over-optimistic goals and strategies by fisheries. It took a long time for fisheries and the associated scientific community to accept that, on the contrary, fisheries may intensify the natural fluctuations of fish stocks, and the consequent extreme annual fluctuations shown by some species are mostly unpredictable (e.g. Karjalainen et al. 2000).

Overall, it must be stressed that complexity and uncertainty at several levels of fisheries systems can be said to be the basic reasons behind unsuccessful fisheries management. Although these essential characteristics of fisheries as resources have long been recognised, it took the dramatic and now well-known collapses of certain fish stocks before researchers, fisheries managers and especially policy-makers and fishers themselves began to realise the significance of the precautionary approach in decision-making (Hilborn and Walters 1992, Ross 1997, Hall 1999, Charles 2001). Some delays in the adoption of this line of thinking have resulted from doubts about how uncertainty should be included in management objectives, practices and decisions. This debate is open, and new tools and approaches are still being devised (Weeks and Berkeley 2000, Hilborn et al. 2001, MacGarvin 2001).

The need to manage fisheries sustainably is a major challenge for the future, particularly since so many varied objectives are involved. The interests of various stakeholders make it hard for decision-makers to protect fish stocks, and ensure that often over-grown fishing communities can be truly sustainable. Improvements are being made in certain areas, but it is far from clear whether they are happening fast enough to avoid further collapses (MacGarvin 2001).

ACKNOWLEDGEMENTS

We wish to thank an anonymous referee for his valuable comments. Fran Weaver has checked English.

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