THE PRECAUTIONARY APPROACH TO FISHERIES AND ITS IMPLICATIONS FOR FISHERY RESEARCH, TECHNOLOGY AND MANAGEMENT: AND UPDATED REVIEW

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Abstract

The uncertainty attached to the available understanding on the bio-ecological, economic and social processes in the fisheries systems are now formally recognized in the major international instruments such as the UN Agreement on the Implementation of the Provisions of the 10 December 1982 Convention on the Law of the Sea Relating to Straddling Fish Stocks and Highly Migratory Fish Stocks (1995) and the FAO International Code of Conduct for Responsible Fisheries (1995). The effective implementation of the precautionary approach in all the aspects of fisheries requires understanding from all concerned. This paper, which follows and updates a document presented in 1994 to the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, clarifies the objectives of the precautionary approach, reviews the trends and perspectives in the perceptions, adoption, and application of the precautionary principle and approach in fisheries, at UNCED, in FAO, UN, ICES, IMO, ICLARM, CCMLAR, and by non governmental organizations (NGOs). The paper examines the issues of uncertainty, error and risk in fisheries and their potential consequences. Subsequently, the paper identifies the implications of the concept of precaution for fisheries research, technology development and transfer, as well as for conservation and management, offering in each case a set of guidelines for implementation. In so doing it offers some analysis of key related issues such as: the burden of proof and the use of the "best scientific evidence" in a precautionary context, the potential for Prior Informed Consent (PIC) and Prior Consultation Procedures (PCPs), Environmental Impact Assessment (EIA), pilot projects and technology lists, the concept of "acceptable impacts", the role of Target Reference Points (TRPs) and Limit Reference Points (LRPs) in precautionary management. In conclusion, the paper proposes a typology of approaches including the preventive, corrective, and precautionary approaches as well as the precautionary principle itself, showing their respective complementary roles in relation to the degree of uncertainty and resulting amount of risk.

INTRODUCTION

There is an obvious link between the sustainable development of fisheries and their precautionary management. In 1988, the 94th Session of the FAO Council agreed that "*Sustainable development is the management and conservation of the natural resource base, and the orientation of* *technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such development conserves land, water, plant genetic resources, is environmentally non-degrading, technologically appropriate, economically viable and socially acceptable.*" This definition applies well to sustainable fisheries development and management.

The strategies required to ensure a high degree of sustainability in human use of natural renewable resources systems are not easy to conceive and implement for at least two reasons: (a) our insufficient understanding of the laws governing these systems and the inherent uncertainty about the consequences of our decisions, and (b) the inadequate nature of our institutions and controls (Holling, 1982; 1994), particularly on access to resources. It is generally agreed that the inadequacy in management results essentially from the open access nature of the fisheries and the lack of effective mechanisms to directly control fishing effort levels in the absence of an explicit agreement on the allocation of resources between users. It is also being realized that, in addition, the problem lies partly in the non-recognition of the high levels of uncertainty that characterize fisheries and the related lack of precaution in most management regimes. The review of the state of world fishery resources undertaken by FAO and the global analysis available in the FAO report on the State of Food and Agriculture (SOFA) show that, although management practice has favourably evolved during the last half century, it has tended to lag behind management theory and that progress towards sustainability, since the first FAO Technical Committee on Fisheries in 1945, has been insufficient. It is now recognized that the biomass of many important fish stocks is close to or even below the level that could produce the maximum sustainable yield (MSY), leading to resource instability and economic losses. A number of fisheries have collapsed ecologically or economically and the situation in the high seas raises particular concern. In many areas, the present situation is one of resource erosion, economic losses and social dislocations that illustrate the fisheries management risk and reflect behaviour which in the last decades has been neither sufficiently responsible nor precautionary (Garcia, 1992; FAO, 1993; Garcia and Newton, 1994; 1995).

The increased recognition that conventional fishery management needed to be improved has been accompanied by a growing concern for environmental management, particularly as a result of the World Conference on Human Environment (Stockholm, 1972), the FAO Technical Conference on Fishery Development and Management (Vancouver, 1973), the FAO World Conference on Fisheries Management and Development (Rome, 1984), the United Nations Convention on the Law of the Sea (hereafter, the 1982 Convention), the work of the Brundtland Commission from 1984 to 1987 (World Commission on Environment and Development, 1987), the United Nations Conference on Environment and Development (Rio de Janeiro, 1992), the International Conference on Responsible Fishing (Cancun, Mexico, 1992) and the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (New York, USA, 1993–1995). Moreover, the emerging awareness of the complexity of marine ecosystems and related scientific uncertainty, particularly in the high seas, and of the risk of error in management, requires an acceleration of the evolution of fishery management, a broadening of its scope and a change in attitudes. Two important and related requirements of the new management context are the need for more caution and for better inter-generational equity. The latter issue concerns the ethics of renewable resource use and the moral obligation placed on the current generation to exploit the resources and enact conservation measures in such a manner as to preserve options for future generations.

The poor control of fisheries development by fishery management authorities is one of the major reasons for the present state of fisheries. In natural ecosystems, the abundance of preys and predators, and their variations, are controlled and maintained within limits compatible with the ecosystems sustainability by a set of complex interactions and feed-back mechanisms. In ecological terms, fisheries are organized "top predators". As such, their survival depends on the survival of their living resources and they are certainly far more sensitive to natural feedback information on the state of the resources they exploit than industrial systems using oceans as a resource for waste-dumping. However, contrary to natural predators, fishermen are not entirely controlled by feedback signals of resource stress. Their operations are not totally dependent on the abundance of the various elements of the resource ecosystem and, indeed, are partly isolated from such feedback controls by various mechanisms such as price increases (as resources become scarcer), technological improvements in efficiency, shifts to other species or areas, and governmental subsidies. They can, therefore, continue and even expand their operations despite the environmental and resource degradation they may produce.

Section 1 of the document defines the objectives of the precautionary approach in the specific field of fisheries. Section 2 proposes some definitions of key concepts used in the document. Section 3 provides an updated review of trends and perspectives in the development in the concepts and applications of the principle of precautionary action, including both the precautionary principle and precautionary approach. Section 4 concentrates on one of the major issues related to, and indeed justifying, precaution such as the uncertainty due to incomplete knowledge, the potential errors in decision-making and the consequent potential risk. Sections 5, 6 and 7 describe the implications of the precautionary approach and provide practical guidance for its application in the respective areas of research, technology development and transfer, and conservation and management. The conclusion provides a summary of the approach and its prospects, focusing particularly on management.

1. OBJECTIVES OF THE PRECAUTIONARY APPROACH

The modern requirement to deal explicitly with uncertainty, in order to reduce risks to the resources and their environment (and indeed to the fishing communities), requires significant changes in the fields of science, technology and fishery management. Such changes are required in order to effectively deal with the unprecedented shift in policy and international relations and with the metamorphosis of public perceptions and political demands resulting from the 1982 UN Law of the Sea Convention, UNCED and its Agenda 21. One of the elements of change is the requirement for a more precautionary approach to natural resources management. The **concept of precautionary action** aims generally at improving conservation of the environment and the resources by reducing the risk of inadvertently damaging them. More specifically, it aims at helping decision-makers and regulators to take a safeguarding decision, when the scientific work is inconclusive but a course of action has to be chosen. In addition, it intends to promote a more equitable balance between the short-term considerations (which led to the present environmental degradation and overfishing) and long-term considerations such as the need to conserve resources for future generations. It aims at promoting inter-generational equity by reducing the cost of our decisions for future generations and by counteracting the effects of current high economic discount rates which provide a strong incentive to overfish, maximizing the discounted net benefits from a stock and, *de facto*, giving preference to present consumption over future consumption[1]. By comparison, and despite the fact that it theoretically aims at sustainability, conventional fishery management addresses primarily, and rather inefficiently, the issue of inter-generational equity and allocation of resources between present users. The concept of precautionary action will also directly benefit present generations of fishers and consumers if fishery authorities and industry actively promote its implementation by other economic sectors whose activities damage ocean productivity, fishing communities' livelihood and consumers' health[2].

[1]This factor often leads to proposals to introduce a social discount rate. However, there are severe practical difficulties in determining and implementing such rates. A more satisfactory solution would appear to be through proper pricing of resources, including not only the marginal cost of harvesting, but also the foregone value of catches no longer available to future generations

[2]Opportunity to promote this approach is given by the growing requirement to integrate coastal fisheries management into the Integrated Coastal Areas Management (ICAM) within which inter-sectoral competition for resources should be organized and controlled

2. DEFINITIONS

The literature on the precautionary principle or approach is loaded with terms the meaning of which may not always be obvious or universally agreed and, in order to facilitate common understanding, this section proposes some definitions with their source. The original ones draw heavily from the discussions in the following sections and should be considered together with them.

Acceptable impact: A negative, or potentially negative, alteration of the exploited natural system, resulting from human activities (i.e., fisheries and other impacting industries), the level and nature of which, on the basis of available knowledge, is considered as representing a low enough risk for the resource, system productivity, or biodiversity. Its acceptability is continuously kept under review and can be revocated on the basis of new knowledge.

Approach: "A way and means of reaching something. The method used in dealing with or accomplishing something" (Houghton Miflin Co., 1992).

Precaution: "An action taken in advance to protect against possible danger or failure; a safeguard. Caution practised in advance. Forethought or circumspection" (Houghton Miflin, 1992). Action taken in advance of scientific certainty but within the bounds of scientific uncertainty, to avoid or minimize negative impact, taking into account the potential consequences of being wrong (modified from a definition in relation to global climate change by Turner, O'Riordan and Kemp, 1991).

Precautionary approach: A set of agreed cost-effective measures and actions, including future courses of action, which ensures prudent foresight, reduces or avoids risk to the resources, the environment, and the people, to the extent possible, taking explicitly into account existing uncertainties and the potential consequences of being wrong[3].

Principle: "A basic truth, an assumption. A rule or standard, especially of good behaviour. A fixed or predetermined policy or mode of action" (Houghton Miflin, 1992)[4].

Reference points: "A (management) reference point is an estimated value derived from an agreed scientific procedure and an agreed model to which corresponds a state of the resource and of the fishery and which can be used as a guide for fisheries management"[5]:

> **Limit Reference Point (LRP)**: indicates the state of a fishery and/or a resource which is not considered desirable. Fishery development should be stopped before reaching it. If a LRP is inadvertently reached, management action should severely curtail or stop fishery development, as appropriate, and corrective action should be taken. Stock rehabilitation programmes should consider an LRP as a very minimum rebuilding target to be reached before the rebuilding measures are relaxed or the fishery is re-opened.
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> **Target Reference Point (TRP)**: corresponds to the state of a fishery and/or a resource which is considered desirable. Management action, whether during a fishery development or stock rebuilding process, should aim at maintaining the fishery system at its level.
>
> **Threshold Reference Point (ThRP)**: indicates that the state of a fishery and/or a resource is approaching a TRP or a LRP, and a which a certain type of action (usually agreed beforehand) needs to be taken. Fairly similar to LRPs in their utility, the ThRPs' specific purpose is to provide an early warning, reducing further the risk that the TRP or LRP is inadvertently passed due to uncertainty in the available information or to the inertia of the management and industry system. Adding precaution to the management set-up, they might be necessary only for resources or situations involving particularly high risk.

Risk: In general, "the possibility of suffering harm or loss; danger. A factor, thing, element, or course involving uncertain danger, a hazard" (Houghton Miflin, 1992). In decision theory "the degree of probability of loss. A statistical measure representing an average amount of opportunity loss" (Kohler, Cooper and Ijiri, 1983). This terminology is used "when large amounts of information are available on which to base estimates of likelihood, so that accurate statistical probabilities can be formulated" (Pass *et al.*, 1991). The Technical Consultation on the Precautionary Approach to Capture Fisheries (FAO, 1995), in this case, refers instead to "*expected loss*" or "*average forecasted loss*" to clearly distinguish between the general meaning and the decision-theoretic one (see also Shotton, 1993).

Risk analysis: "Any analysis of unknown chance events for purposes of effecting or evaluating decisions in terms of possible penalties and benefits attending these events. A method for generating different probability distributions with accompanying cost and benefits that may attend different courses of action. Generally uses computer simulations" (Kohler, Cooper and Ijiri, 1983).

Uncertainty: "The condition of being uncertain. Doubt. Someting uncertain. In statistics, the estimated amount or percentage by which an observed or calculated value may differ from the true value" (Houghton Miflin, 1992). "The incompleteness of knowledge about the states or processes in nature" (FAO, 1995).

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[3]There is paradoxically no definition of the precautionary approach which is generally related to the need to take action even in the absence of "full scientific certainty" and defined by its implications. This definition has been developed by the author based on the definitions of "precaution" and "approach", above, and on UNCED Principle 15

[4]It can be noted that while the first part of this definition differentiates between the precautionary "principle" and "approach", the second part tends to blur the difference between the two concepts

[5]According to the *ad hoc* Working Group on Reference Points established by the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks in New York, in March 1994 (cf. Annex 5)

3. TRENDS AND PERSPECTIVES

There is no explicit reference to the principle in the 1982 Convention. Part XII, on "Protection and preservation of the marine environment", does not contain detailed instruments for implementation of the conservation of the marine ecosystem, but it does state in a global instrument, in article 192, the following general obligation: "*States have the obligation to protect and preserve the marine environment*" (Burke, 1991). In addition, ecosystem conservation also requires measures for the fisheries sector, striking a balance between the provisions for environmental conservation and fisheries management to ensure sustainable exploitation.

However, in fisheries, the concept of precautionary action seem to have progressively become an important factor in negotiations between States to establish management measures in circumstances where there is an obligation to negotiate in good faith to reach agreement (e.g., with respect to highly migratory, straddling or shared fish stocks, under the 1982 Convention). It can be assumed that, given the wide support for this concept in environmental law, a State which refers objectively to it will hope that it cannot be accused of bad faith (Burke, 1991). The concept is also developing in national fisheries management regimes. The concept of precaution has been expressed as "the **precautionary principle**" (hereafter, the principle) or "the **precautionary approach**" (hereafter, the approach). Although the two terms relate equally well to the concept of caution in management, and sometimes not differentiated by scholars (e.g., Bodansky (1991) uses the two terms alternatively), they are differently perceived by international lawyers, negotiators and industry, as shown below. The term "approach" is apparently more generally accepted by Governments in the fisheries arena because it implies more flexibility, admitting the possibility of adapting technology and measures to socio-economic conditions, consistent with the requirement for sustainability. It is particularly more appropriate for fisheries because consequences of errors in their development or mismanagement are unlikely to threaten the future of humanity and, in most cases, are reversible. On the contrary, the term "principle" has developed a negative undertone because it is usually given a radical interpretation and has led to the outright ban of technologies, e.g., in the case of whaling (Bodansky, 1991) and the Large Scale Pelagic Driftnet Fishing (see below), and is sometimes considered incompatible with the concept of sustainable use. These two concepts are further elaborated below.

3.1 The Precautionary Principle

This principle's most characteristic attributes are that: (a) it requires authorities to take preventive action when there is a risk of severe and irreversible damage to human beings; (b) action is required even in the absence of certainty about the damage and without having to wait for full scientific proof of the cause-effect relationship, and (c) when there is disagreement on the need to take action, the burden of providing the proof is reversed and placed on those who contend that the activity has or will have no impact.

It seems generally agreed that the precautionary principle has originated in Germany as the "Vorsorgenprinzip" (Dethlefsen *et al.* 1993). The principle has been referred to and applied at national level in relation to human activities with potentially severe effects on human health (engineering, the pharmaceutical and chemical industries, nuclear power plants, etc.). In international environmental law, the principle has emerged as a recognition of: (a) the uncertainty involved in measuring the impact of toxic substance on the ecosystem and the human health, and (b) deciding on the "assimilative capacity" of such ecosystems (i.e., their ability to absorb a certain quantity of the substance in question without unacceptable impacts). In the 1970s, following the 1972 Stockholm Conference, concern for human safety was progressively extended to the human environment and to other species. This led to increasingly frequent reference to the principle in international agreements and conventions, often with limited consideration of its practical implications. It has been introduced at international level at the First International Conference on the Protection of the North Sea (1984) in relation to persistent toxic substances susceptible to bioaccumulation in the marine ecosystem. The 1987 Declaration of this Conference contains an example of the concept of precaution in relation to coastal States' jurisdiction, habitats, species and fisheries, including pollution from ships. It provides that "*States accept the principle of safeguarding the marine ecosystem by reducing dangerous substances, by the use of the best technology available and other appropriate measures*" and that "*this applies especially when there is reason to assume that certain damage or harmful effects on the living resources are likely to be caused by such substances and technologies, even where there is no scientific evidence to prove a causal link between practices and effects.*"

The scope of application of the precautionary principle was successively broadened from persistent toxic substances to all synthetic persistent substances, natural substances released in large quantities (e.g., nutrients responsible for eutrophication) and finally to all emissions responsible for global warming (Dethlefsen *et al.*, 1993). The principle has been invoked in issues related to the ozone layer (1985 Vienna Convention for the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer) where States agreed to reduce emissions of certain substance at a time when the causal links had not yet been firmly established (Boelaert-Suominen and Cullinan, 1994). It has also ben referred to in relation to the greenhouse effect and the conservation of nature. It has touched indirectly on fisheries through provisions in the international convention on dumping at sea (the Paris and Oslo Conventions, Marpol) relating to pollution by fishing vessels. The 1991 International Conference on an Agenda of Science for Environment and Development into the 21st Century (ASCEND 21) referred to the principle, stressing "*the central importance of the precautionary principle according to which any disturbance of an inadequately understood system as complex as the Earth system should be avoided*". Broadus (1992) asked whether that meant "any disturbance" and at "any cost" indicating that the principle was not a principle but a range of more-or-less rhetorical prescriptions for choice in front of uncertainty. The principle has also been considered as particularly appropriate in the context of Integrated Coastal Areas Management (Boelaert-Suominen and Cullinan, 1994) because of the vulnerability of coastal resources, the likelihood of swift and irreparable harm, and the incomplete understanding available on the complex web of interconnected biological processes in the coastal area. More recently, the precautionary principle has also implicitly been included in the Convention on Biological Diversity (UNEP, 1992) which noted, in its preamble "*that, where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimizing such a threat.*"

The principle remains contentious both within the scientific community and from the point of view of policy-makers and these controversies are illustrated in the fact that there is, as yet, no generally accepted formulation of the principle. When the interpretation of the principle is softened, the border between it and the approach is significantly blurred. For instance, Young (1993, cited by Dovers and Handmer, 1995), proposes to consider four different levels of application of the principle, corresponding to decreasing levels of risk, potential degree of irreversibility, and uncertainty:

> Level 1: Impacts are potentially serious (unacceptable) or irreversible and uncertainty is high: a strict application of the principle is required, insisting on complete reversibility and putting a strong burden of proof[6] on development proponents.
>
> Level 2: Impacts may be serious but potentially reversible and a reasonable amount of data is available to appreciate risk: large safety margins should be ensured in assessments and decisions and use of the best available technology should be strictly required, i.e., regardless of costs.
>
> Level 3: Impacts are considered largely acceptable (and/or potentially reversible) and reasonably good scientific and other information is available: lower safety margins are accepted. The best available technology is required only if economical.
>
> Level 4: Potential losses are considered neither serious nor irreversible: decisions could be based on traditional cost-benefit analysis.

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[6]See discussion on the burden of proof in Section 5

The conditions for the application of levels 3 and 4 and their implications are very similar to the conditions and implications of the precautionary approach and illustrates that these two related concepts are sometimes difficult to distinguish.

The large-scale pelagic driftnet issue

The UN General Assembly Resolution 44/225 of 22 December 1989, on large-scale pelagic driftnet fishing and its impact on the living marine resources of the world's oceans and seas, could be considered a case of radical application of the concept of precaution, despite the lack of explicit reference to the principle. The resolution expressed concern about the size of the fleets, the length of the nets, their mode of operation, their potential impact on anadromous and highly migratory species, their by-catch and the concern of coastal countries on the state of resources close to their exclusive economic zones. It recommended that a worldwide moratorium should be imposed on all driftnet fishing by 30 June 1992 and it established a set of immediate and regionally tailored interim measures. It also provided that such measures would not be imposed in a region or, if implemented, could be lifted, should effective conservation and management measures be taken upon *statistically sound analysis* to be made jointly by concerned parties. The proposal is rational but the flaws in the process followed for the implementation of the resolution have been underlined (Miles, 1992, 1993; Burke, Freeberg and Miles, 1993).

The consequences of this resolution, after heated international debate and political pressure, has led to the discontinuation of the issuance of fishing licences and research for alternative fishing techniques, in Japan and Taiwan (Province of China); the docking and conversion of driftnet fishing vessels in the Republic of Korea and a regulation by the European Union (see below). Large-scale driftnet fishing stopped in the South Pacific in 1992–93 but some fishing continued in the Mediterranean and Bay of Biscay, where scientific experiments were conducted to assess the fishery's impact on the associated small cetaceans. Many other Mediterranean countries, however, have taken regulations prohibiting driftnet fishing in their waters. Following up on the UN Resolution, the European Community adopted a Council Regulation (N° 345/92 of 27/1/1992) limiting to 2.5 kilometres the length of the driftnets authorized, but granting a derogation to 5.00 kilometres, until 31 December 1993, to vessels having fished for at least three years preceding the implementation of the regulation. This derogation was to expire by the indicated date unless scientific evidence showed the absence of "*any ecological risk*".

3.2 The Precautionary Approach

In considering the introduction of more precaution in fisheries management and development, the main differences between fisheries impacts and chemical industries pollution (for the control of which the precautionary principle was created) must be kept in mind:

a. the assimilative capacity in relation to fisheries impact (i.e., the quantities of fish that can be removed without damaging the system's productivity) exists without doubt and can be determined with some accuracy, even though it varies, and

b. the impacts are, in most cases, reversible and, as a result, the potential consequences of an error would rarely be dramatic, even though they can be significant in socio-economic terms.

In the early 1990s, the precautionary approach has been progressively more accepted and its field of application has been broadened to include the management of natural renewable resources, including fisheries. The aims of the precautionary approach are similar to those of the precautionary principle from which the approach is sometimes difficult to distinguish. The main difference between the principle and the approach might be that the latter considers explicitly the social and economic implications of its application in order to ensure that: (a) it does not lead to imbalance in favour of non-fishery uses and future generations with undue strain on present generations and the fishery sector, and (b) that unavoidable short-term costs to the fishery sector are mitigated and equitably shared. The various interlinked processes that lead to the widespread adoption of the precautionary approach in fisheries, are briefly described below.

The UNCED process

UNCED stressed the need for a precautionary approach to ocean development in its Rio Declaration and in Agenda 21, particularly in its chapters on the management of coastal areas, resources under national jurisdiction and high seas resources. The principle 15 of the Declaration states that "*in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation.*" The wording, largely similar to that of the principle, is subtly different in that: (1) it recognizes that there may be differences in local capabilities to apply the approach, and (2) it calls for cost-effectiveness in applying the approach, e.g., taking economic and social costs into account. UNCED led to agreement on two principles which are intuitively reasonable and potentially contradictory: the precautionary approach and the principle of economic efficiency. The delicate co-existence of these two principles impedes the development of safeguards against uncontrolled decisions (or lack of decisions).

The FAO process

Many years before the issue became fashionable in the fisheries circles, FAO, through its European Inland Fisheries Advisory Commission (EIFAC), collaborated with the International Council for the Exploration of the Sea (ICES) in the development of ICES/EIFAC Codes of Practice and Manual of Procedures for Consideration of Introduction and Transfer of Marine and Freshwater Organisms (Turner, 1988)[7]. This Code stresses that, in a context of rapidly changing population pressures, the impact of the introduction of species to enhance the potential of sustainable fisheries should be examined in the light of the likely impacts of alternative development strategies, involving environmental degradation and likely to result in changes in species composition of both the terrestrial and aquatic ecosystems.

More recently, in a review of the FAO programme in marine fisheries management, Garcia (1992) identified some of the challenges to be faced by fisheries in the period 1993–2000. These included: the uncertainty in the scientific information, the need for a more precautionary approach to management, the burden of proof and the need to define "acceptable" levels of impact. At the 1992 FAO Technical Consultation on High Seas Fishing, Garcia (1992a) stressed the uncertainty in the "best scientific evidence available" for management and drew attention to issues of precaution and burden of proof, the non-precautionary nature of the traditional MSY reference point, and the need for more and different reference points to be used as a basis for more precautionary management strategies. The Consultation provided guidance to the Fisheries Department of FAO on how to proceed (FAO, 1992) and, *inter alia*, agreed that:

- fisheries should be managed in a cautious manner;
- precaution did not necessarily require a moratorium on fishing;
- there was a need to identify methods to handle uncertainties;
- the objective was to safeguard both people's livelihood and biodiversity;
- existing precautionary measures should be included in the Code of Conduct;
- precautionary measures should be based on science and not be discriminatory, and
- measures should be revised or revoked when new information became available.

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[7] A full-scale practical application of this Code has been undertaken by FAO in Papua New Guinea (Coates, 1994). starting from the premise that introductions of new species in an aquatic ecosystem should be subject to prior evaluation. irrespective of whether species are "exotic" or not

The International Conference on Responsible Fishing (Mexico, 6–8 May 1992), organized in close cooperation with FAO, defined the concept of responsible fishing as encompassing "*the sustainable utilization of fishery resources in harmony with the environment; the use of capture and aquaculture practices which are not harmful to ecosystems, resources or their quality; the incorporation of added valued to such products through transformation processes meeting the required sanitary standards; the conduct of commercial practices so as to provide consumers access to good quality products*". The Cancun Declaration contains a fairly complete prescription for modern fishery management covering environmental impacts; multispecies by-catch and discards issues; effort control requirements; etc., but did not include any explicit reference to the precautionary approach. One year later, however, the Inter-American Conference on Responsible Fishing (Mexico City, July 1993) referred to the need to take precaution into account in the Code of Conduct on Responsible Fishing, particularly in the high seas.

In 1993, the review of the state of highly migratory species and straddling stocks, prepared by FAO at the request of the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks indicated that it was necessary "*to analyse the potential role and agree on possible ways of implementing cautious management approaches compatible with sustainable fisheries*" (FAO, 1994, page 65). Following a first attempt to analyse in detail the various implications of the concept of precautionary action in fisheries research, management and development (Garcia, 1994), a document was prepared by FAO, to comply with a request by the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (Second Session, July 1993). This document (United Nations, 1994; Garcia, 1994a) was presented to the UN Conference at its meeting of March 1994. Even though it was prepared for a meeting on straddling and highly migratory resources, the document was considered by FAO as generally pertinent for all resources and fisheries, whether in the high seas or under national jurisdiction, because it was felt and stated that, if a resource required precaution, it should be provided regardless of the type of jurisdiction, and the set of management measures applied to the various life stages of a transboundary resource should be coherent across its entire area of distribution. Unfortunately, this logical and basic biological requirement became, at the UN Conference, one of the major points of disagreement because some coastal countries considered that the need for overall "coherence" or compatibility between the management regimes inside and outside the EEZ could represent or be interpreted as an encroachment on their sovereign rights[8].

The issues of scientific uncertainty and precaution were also addressed in another document prepared by FAO for the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, on management reference points (United Nations, 1994a; FAO, 1994). This report recognized that "*most of the difficulties experienced in using any target reference point results from the considerable uncertainties as to the current position of the fishery in relation to it*". It suggested using limit reference points (LRPs) as a way to increase the precautionary nature of the management set-up. Such LRPs, to be used alone or in combination, could correspond, for example, to situations where: (a) spawning biomass or proportion of mature individuals fall below, say, 20% of the values for the virgin stock; (b) fishing mortality falls below, say, 30% of the virgin stock biomass-per-recruit or reaches 80% of the rate of natural mortality; (c) total mortality reaches the level corresponding to Maximum Biological Production for the stock; (d) mean individual size fall below the mean size at maturity; (e) annual recruitment levels remain below a certain level (or average level) for a certain number of years, and (f) the resources rent have been totally dissipated (i.e., the total cost of fishing, including reasonable revenues to manpower and capital, are equal to total revenues), etc.

[8] A situation could be foreseen in which a sovereign coastal State could see its right to introduce a technology (e.g., a new fishing gear, or practice, or genetically modified organisms) questioned by non coastal countries exploiting the same straddling or highly migratory stock

FAO has started the preparation of a **Code of Conduct for Responsible Fisheries** following the International Conference on Responsible Fishing, held in Cancun (Mexico, 1992). The Code includes a section on precautionary approach as part of the Article 6 on Fisheries Management[9]. The implementation of the Code of Conduct will be facilitated by a series of specific guidelines, one of which will address the precautionary approach to fisheries management (including aspects related to the introduction of new species). The precautionary approach promoted by FAO is being progressively reflected in the fishery sector reality. The applications to inland fisheries and aquaculture have been already mentioned above. In addition, in the last session of the Working Party on Resources Evaluation of the Committee for Eastern Central Atlantic Fisheries (CECAF) it was recommended that, *as a precautionary approach*, the fishing effort exerted on horse mackerels in Morocco, Mauritania, Senegal and Gambia, should be kept at the level as in the late 1980s. A practical application of the precautionary approach to management of tropical shrimp fisheries has also been proposed (Garcia, 1996) illustrating the possibility to make maximum use of the available scientific information, with its uncertainty, to elaborate precautionary management advice.

More recently, and in direct relation to the process of development of the FAO International Code of Conduct, the Government of Sweden, in close cooperation with FAO, held a Technical Consultation on the Precautionary Approach to Capture Fisheries (Including Species Interaction) in Lysekil, Sweden, 6–13 June 1995 (FAO, 1995). This meeting drafted a set of guidelines (which will support the Code of Conduct) and produced a number of technical background documents dealing in detail with specific technical issues addressed in the guidelines (Fitzpatrick, 1995; Hilborn and Peterman, 1995; Huppert, 1995; Kirkwood and Smith, in press; Rosenberg and Restrepo, 1995). including the present review.

The United Nations process

At its first substantive session, held at New York in July 1992, the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks (hereafter called the Conference) also addressed the issue. It could not reach consensus on the precautionary principle, which many countries equated with a moratorium on fishing and considered too radical for such environmentally soft industries as fisheries. A consensus developed instead on the need to introduce or strengthen the precautionary approach to fishery management. During its Second Session, in July 1993, the Conference considered again the issue. The Chairman negotiating Text (A/CONF.164/13*) contained only one reference to the precautionary approach, in Article 4: "*Use of the precautionary approach shall include all appropriate techniques, including, where necessary, the application of moratoria*". A paper submitted at this meeting by Argentina, Canada, Chile, Iceland and New Zealand (United

Nations, 1993) proposed selected precautionary measures on the High Seas, distinguishing between existing and newly discovered fisheries. **For existing fisheries**, the text suggested *inter alia* that: (a) TACs and effort limitations shall be established to maintain exploitation rates below the level of MSY and, where appropriate, to allow the stock to rebuild; (b) precautionary management thresholds shall be established at which pre-determined management courses of action should be taken; (c) where stocks decline over time, TACs and effort shall be reduced to arrest the decline and subsidies for fishing operations shall be stopped, and (d) by-catch limitations should be established and stocks of associated or dependent species should be maintained or restored. **For newly discovered stocks**, the text suggested also that: (a) early large-scale development of fisheries on newly discovered stocks shall be prohibited and limitations shall be applied immediately on effort and on Government assistance, and (b) precautionary Total Allowable Catches (TACs) and quotas shall be established below the MSY level. In addition to these largely technical measures aiming at increasing precaution, the document contained proposals aiming at giving to the coastal States special prerogatives to establish interim management measures: (a) in case of discovery of a new straddling or highly migratory resource and (b) when the coastal State has established that an emergency exists. The heated debate on this latter aspect of the proposal has overshadowed the other aspects of the proposal.

[9]The text of this section (Annex 1) is only provisional and will be revised on the basis of the outcome of the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks

Nonetheless, during its 1993 Session, the Conference requested the Food and Agriculture Organization (FAO) to prepare two information papers: one on the precautionary approach in fisheries management and one on management reference points. During its Third Session, in March 1994, the Conference considered again the issue of precaution, based on the document prepared by FAO and the proposals included in paragraph 5 of the Chairman's Negotiating Text (Annex 2) which referred specifically to the precautionary approach to management. Two working groups were held: on the precautionary approach and on management reference points. The outcome of the heated debate on precaution during the following sessions of the Conference was reflected in a number of modifications of the draft Chairman Negotiating Text which represented a substantial elaboration on the approach (cf. Annex 3 and 4). The UN *ad hoc* Working Group on Management Reference Points reached consensus on all but one of a set of Technical Guidelines on Biological Reference Points (see Annex 4). The only serious conflictual point, already referred to above, related to the need for coherence in management measures across the area of distribution of the species.

The NGOs process

Non-Governmental Organizations (NGOs), both international and national, environmental or professional have participated actively in the UN process, lobbying for recognition of the need for a precautionary approach to fisheries which would involve, *inter alia*:

- taking decisions even with inadequate evidence;
- reversing the burden of proof;
- requesting Environmental Impact Assessments;
- avoiding non-reversible impacts;
- adopting management reference points;
- establishing action-triggering thresholds points;
- allowing people's participation;
- promoting transparency;
- establishing sanctuaries;
- taking into account combined stresses on resources;
- reducing by-catch and increasing selectivity;
- conserving also associated and dependant species;
- testing management regimes robustness;
- allowing new fisheries only at very low pilot level;

- establishing dispute settlement mechanisms, and
- promoting inter-generational equity.

NGOs have generally welcomed the FAO efforts towards the operationalization of a precautionary approach to fisheries which recognized the need to: (a) apply it to all fisheries; (b) apply it throughout the stock range, and (c) agree on criteria and actions to be taken before a crisis occurs. Despite complaints of insufficient opportunity for interaction in the Code of Conduct process by some NGOs, it is clear that there is a large coincidence between the NGOs' proposals and the FAO code and guidelines. Some environmental NGOs, however, considered that the FAO approach was too much oriented towards the protection of the fishery sector, making excessive reference to the socio-economic burden associated with it. Some criticized the proposed use of "reversibility" as a criteria for acceptability, considered as a loophole. A fishermen's association, on the contrary, considered that some the FAO proposals were unbalanced, setting an impossible burden for industry. It is clear that more interaction is needed even though there is a basic agreement on what should be done. Expectations of Governments and NGOs may never be identical and differences will also exist between different NGOs. It is therefore probably not reasonable to expect full agreement, by everyone, on all aspects of such a critical issue.

International Council for the Exploration of the Sea (ICES)

Another example of the precautionary approach can be found in the form in which the Advisory Committee on Fisheries Management (ACFM) of the International Council for the Exploration of the Sea (ICES) delivers its advice to its member States. The ACFM states that "*for stocks where, at present, it is not possible to carry out any analytical assessment with an acceptable reliability, ACFM shall indicate precautionary total allowable catches (TACs) to reduce the danger of excessive efforts being exerted on these stocks*" (Serchuk and Grainger, 1992). The implicit assumption in the ACFM advice is that, in the absence of scientific assessments, uncontrolled fisheries are likely to build up overcapacity and overfish the resources. The preventive action is to establish TACs at conservative levels to limit fishing until better assessments become available. The implication is that such conservative measures would be lifted only if better information, in the form of an acceptable analytical assessment were provided.

In addition to the work on species introductions undertaken with FAO-EIFAC (referred to above under the FAO process), ICES also developed a Code of Practice on the Introduction and Transfer of Marine Organisms (ICES, 1995) dealing more specifically with the introduction of Genetically Modified Organisms (GMOs). It is worth noting in this respect that in considering this Code of Practice, the FAO-SWEDEN Technical Consultation on the Precautionary Approach to Capture Fisheries (FAO, 1995) indicated that "*because of the high probability and unpredicted impacts, many species introductions are not precautionary*" and that "*a strictly precautionary approach would not permit deliberate introductions and would take strong measures to prevent unintentional introductions*".

International Maritime Organization (IMO)

Although not directly related to the fishery sector, the efforts of IMO to reduce the impact of accidental introduction in ballast water and sediment of tankers as well as hull fouling, are worth mentioning. Such accidental introductions are numerous and have resulted in serious damage to the fisheries and aquaculture ecosystem and resources in some cases (Bartley and Minchin, 1995; Mee, 1992; Zaitsev, 1993). The IMO guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens from Ship's Ballast Water and Sediments (IMO, 1994) addresses the issue and aim at minimizing the risk of introduction. The issue was also addressed by the FAO-SWEDEN Technical Consultation on the Precautionary Approach to Capture Fisheries (FAO, 1995) which stressed that present practices were largely non-precautionary and that major changes in behaviour, technology and enforcement were required.

The World Conservation Union (IUCN)

The IUCN view on precaution is that "*a precautionary approach should underlie all fisheries management, rather than being restricted to special cases*" and that "*major interventions in the natural environment should not be conducted in the absence of information to assess the potential consequences*" (Cooke, 1994). Cooke stressed that it was necessary be not only set and declare the management objectives but also to ensure (through scientific simulations or otherwise) that the management procedures in place result in a high probability to meet these objectives under a wide range of scenarios with respect to stock dynamics and ecological interactions. In order to qualify as "precautionary" a management approach would therefore have "*to be sufficiently fully specified to enable its simulation, and to pass at least a minimum checklist of tests*". Cooke, further proposed that authorized levels of catches be inversely related to the amount of data available and that considerations related to protection of fishery habitats, non-target species and biodiversity be included in a precautionary approach. When describing the elements needed to test a management procedure, Cooke lists all the sources of uncertainty regarding the stock, required to predict how the stock might behave (e.g., sampling variability and biasses; uncertainty and long-term fluctuations in stock productivity, dynamics and structure, recruitment, mortality and growth and interactions with other species). Conspicuously lacking from the recommended approach are, however, all the important and often driving sources of uncertainty regarding the fishery sector itself, the fleet and capital dynamics, the alternative employment, the fishermen's behaviour, etc. Without such elements, simulation of management systems in most fisheries would be fairly unreliable.

International Center for the Living Aquatic Resources Management (ICLARM)

The International Center for Living Aquatic Resources Management (ICLARM) has recently developed its position regarding the introduction of species and the need for a precautionary approach (Pullin, 1994) which promotes adherence to the ICES-EIFAC guidelines and acknowledges the potential impact of genetically modified organisms.

Commission for the Conservation of the Antarctic Marine Living Resources (CCAMLR)

While not referring to the precautionary approach explicitly, the CCAMLR Convention includes important principles of ecosystem conservation[10] such as:

- " *Prevention of decrease in size of any harvested population to levels below those which ensure stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest net annual recruitment;*
- *Maintenance of ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above;*
- *Prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impacts of harvesting, the effect of introductions of alien species, the effect of associated activities on the marine ecosystem, and of the effects of environmental changes, with the aim if making possible the sustainable conservation of the Antarctic marine living resources.*"

[10]Conservation taken as explicitly including sustainable use

The last principle is particularly typical of the precautionary approach as it addresses the concepts of risk and reversibility in a broad ecosystem concept (see Kirkwood and Smith, in press) for more details. CCAMLR has also introduced precautionary catch limits for krill fisheries (in 1991 and 1992) and for *Electrona carlsbergii* (in 1993). It instituted, in 1992, the requirement for advance notification and data requirements prior to the development of a new fishery. Finally, in 1993, in the absence of sufficient data for the establishment of a management regime, it authorized the starting of an experimental fishery for the crab *Paralomis* spp.

4. UNCERTAINTY, ERROR AND RISK

Uncertainty

In the definition section above, uncertainty has been defined as "*the condition of being uncertain. Doubt. Something uncertain. In statistics, the estimated amount or percentage by which an observed or calculated value may differ from the true value*" (Houghton Miflin, 1992) or as "*the incompleteness of knowledge about the states or processes in nature*" (FAO, 1995)

The incompleteness of knowledge derives from: (a) ignorance (i.e., no data at all); (b) inaccuracy (i.e., potential bias in the data), and (c) variance (i.e., statistical confidence limits of the data). More specifically, statistical uncertainty (or variance) is related to stochasticity or error from various sources estimated using statistical methods. In its taxonomy of uncertainty, Wynne (1992) distinguishes between: (a) risk, when the system is basically known and outcomes can be assigned a probabilistic value; (b) uncertainty, when important parameters are known, but not the probability distributions; (c) ignorance: identified lack of knowledge of parameters and relations known to exist and for which are researchable, and (d) indeterminacy: when causal chains and processes are open and thus defy prediction. In decision theory, it is indeed customary to refer to "risk" and "uncertainty" when referring to situations where the outcome of a particular event is unknown, but to use "risk" when the probability of the future event is quantifiable ("knowable") and "uncertainty" when such probability is unmeasurable ("unknowable") (Luce and Raifa, 1957; Knight, 1965; Granger and Henrion. 1993). For a discussion on the use of the terms "risk" and "uncertainty" in fisheries, see Shotton, 1993.

In fisheries, the impact of the extracting activity on the resources and the environment needs to be accurately assessed and forecast in order to propose management options reducing to a minimum the possible risk of severe and costly or irreversible crisis[11]. However, the scientific understanding of the fisheries ecosystems and capacity to predict their future status in accurate quantitative terms is limited by the properties of fishery resources, their "fluid" nature and interconnectedness; the limited knowledge on genetic stock structure and impacts of fishing on resources genetics; the complexity of the interactions between species and gears and fisheries; the poor quality of the available fishery data; the limitation of scientific models and research funds, and the fluctuations of economic parameters. This leads to a degree of uncertainty in the scientific, technical, economic and political information upon which managers and industry leaders base decisions which may not always be wholly appropriate. There are numerous illustrations of this and the most recent relates to the management of the Northern Cod stock in the Northwest Atlantic where, following a collapse of the resources, it was necessary to establish a very expensive emergency welfare programme to support a stunted coastal fishery sector. A polemic has started as to whether research, management, industries, national decision-makers or foreign fleets, were responsible for the mistakes (Finlayson, 1994) and it appears that, as usual, the responsibilities are to be shared and the debate comes too late.

Scientists have repeatedly addressed the issue of uncertainty and the related risk, trying to find ways of identifying and quantifying better the levels of uncertainty in their statements as well as more robust (forgiving) management approaches (Walters and Hilborn, 1978 and 1987; Shepherd,1991; Smith, Hunt and Rivard, 1993). Hilborn (1992) distinguishes between "*noise*", "*uncertain states of nature*" and "*surprises*". Noise includes the elements of uncertainty for which historical experience is available, such as year-to-year variations in weather, prices, administration decisions, political setup and directions, etc. and for which probabilities can be usually worked out. Uncertain states of nature refer to elements of uncertainty that have been explicitly identified but for which no experience is available and, therefore, no probabilities can be obtained. These include, for instance, major shifts in ecosystem structure, impact of global change, etc. Surprises refer to elements of the uncertainty that were never considered.

Errors

When decision-makers take the necessary decisions, while both the present situation and the future outcomes are not fully understood, they implicity accept a certain probability to make some mistake and make the assumption that this mistake will either have a negligible cost or would be easily corrected. Errors that might be made may affect: (a) the basic fishery data used for analysis such as on catches, effort, sizes landed, etc. (**measurement error**); (b) the estimation of populations and parameters derived from such data (**estimation error**); (c) the understanding of relationships between the different elements of the fishery system and their interaction (**process errors**); (d) the way these relationships are mathematically represented (**model error**); (e) decisions that management takes on the basis of such information (**decision error**), and (f) the way in which management measures are implemented (**implementation error**). The errors affect both the biological, economic and social component of the fishery system. They may affect, for example, the decision-maker's expectation regarding fishermen's reaction to a proposed measure, as a consequence of errors in the explicit or unformulated behavioural model, used in forecasting such a likely reaction. Management errors can lead to two types of situations:

a. **necessary management measures were not taken** and, as a result, the resource is damaged. There are short-term costs for the resource and, possibly, for the fishing community if not compensated by government subsidy. The biological impact is usually reversible if a corrective measure is applied, except perhaps in the case of major damage to the habitat. This type of error may also carry the risk of major economic consequences (e.g., in Peru or. more recently, on the Eastern Coast of Canada), and

b. **unnecessary management measures were taken** and, as a result, fishing activities were curbed. The cost of the error is borne by the fishery. The biological effects of the measure, if any, would usually be positive and reversible soon after the measure is suppressed. The socio-economic impact may or may not be reversible (e.g., where there the error resulted in the loss of the market).

[11] See a detailed discussion on fisheries impacts in the section on Management Implications

It must, therefore, be accepted that management decisions addressing actual or perceived risks will often be necessarily taken with less than complete and accurate information which may lead to errors. The question is: how to deal with the problem while minimizing the risk of error in the short and long-term? The responses are: (a) improving information to reduce the level of uncertainty, and (b) improving robustness of decision-making to a given level of uncertainty. Improving information and understanding to the point of reducing substantially the risk of error implies data and financial resources requirements which would often be unrealistic, particularly for high seas or highly unstable resources. As a consequence, while research efforts should be pursued, efforts have tobe made to improve decision-making. Hilborn (1992) distinguishes two types of management response to uncertainty. The "*blind faith strategies*" are based on the best available evidence and applied without any explicit feed-back mechanism for improving them on the basis of performance. These strategies are also called "*open-loop strategies*" in optimal control theory. On the contrary, "*learning strategies*" explicitly provide for adaptation and improvement on the basis of more or less active learning gained from experience and surprises. Most management system "learn" but usually do so in a passive or reactive mode, at a very low pace and at the price of costly crises. Active learning would improve performance by accelerating strategy optimization through feed-back loops, and involves "*taking management action deliberately designed to be informative in addition to the explicit monitoring and regulation function of management*".

Risk

In the section on definitions, risk has been described as "*the possibility of suffering harm or loss. A factor, thing, element, or course, involving uncertain danger, a hazard*". This is the general meaning intended in most environmental conventions. In more technical literature, risk refers to potential negative consequences (or undesirable outcomes) of a decision, quantitatively assessed and often referred to as "*expected loss*" or "*average forecasted loss*". Turner, O'Riordan and Kemo (1991) stress that "*risk is not merely an objective phenomenon but a hazard clothed with social meaning* *and judgement*".

No matter how much effort is made in research and through adaptive learning, acertain level of uncertainty will remain and, therefore, a certain level of risk when making decisions. A fishery management strategy aiming at no risk at all for the resource and the fishing communities would imply either research costs beyond the value of the fishery or no development at all (in the case of an extreme interpretation of the concept of precaution). Few Governments would find either of these two extreme options viable. Cautious management will therefore deal explicitly with risk and aim at a compromise and it should be clear that the higher the uncertainty and/or risk the greater will be the need for caution, particularly in the selection of management reference points (FAO, 1993a). Particular caution may be necessary when resources and people are in a highly vulnerable situation as, for example, in small island countries where the erosion of natural resources may lead to the degradation of the coral reef ecosystem and, beyond a certain threshold, to the breakdown of development opportunities, life support and social order. An important and difficult task for cautious management authorities will be to develop a societal consensus about the nature and levels of the biological and societal impacts (and risks) that might be considered acceptable (tolerable) and to highlight and address the fundamental trade-off implications of the decisions, for different elements of the society and for both the short- and long-terms. Shrader-Frechette (1995) stress that the development of such a consensus would benefit from a science-based **comparative risk assessment**, to improve the objectivity of possible perceptions of risk and ranking of the various threats to the aquatic system and the fisheries. Such assessment would also help optimize the allocation of human and financial resources available for research, technology development and management. It must be accepted, however, that people are concerned not only with ecological risk, e.g., resource depletion, but also with inequities with regard to risk distribution, lack of concertation on acceptable risks, inadequate insurance or compensation for risk and other non-quantifiable aspects of risk which cannot be easily captured by comparative risk assessment and simple cost-benefit analyses.

Solutions often proposed to the problem of uncertainty tend to be simplistic (e.g. take the "lower bound" of the range) or oversimplistic (discontinue an activity, do not allow it to start), neglecting to compare the cost of this decision to the resulting benefits. Shane and Peterman (in preparation) stress that a precautionary measure "can only be justified if it improves management performance, i.e. if the benefit of reducing overfishing exceeds the cost of reducing harvests". They suggest whether adjustments to take uncertainty into account are worthwhile and how large they should be.

5. IMPLICATIONS FOR FISHERIES RESEARCH

All expressions of the concept of precaution require that the "*lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation*" (Principle 15 of the Rio Declaration). The requirement for precaution may, therefore, have been interpreted as requiring no input from fishery research. Gray (1990), for instance, stated that the "*acceptance of the precautionary principle has nothing to do with science*" and that it leads to arguments "*that do not have the required objectivity and statistical validity*". In practice, however, and as proposed below, the effective implementation of precaution requires substantial support from fishery science, which needs to be adapted to the new requirements.

5.1 The "Best Scientific Evidence Available"

Scientific cooperation to develop a consensus on the state of nature and cause-effect relationships, appropriate models and the potential consequences of fishing has been the basis for cooperation in international fisheries management and the major "raison d'être" of ICES and it should continue to be one of the most neutral contributions to the resolution of conflict between nations and competing user groups. The Christiania Conference, in 1901, held just before the creation of the International Council for the Exploration of the Sea (ICES), endorsed the principle of scientific inquiry as a basis for rational exploitation of the sea. The same principle was also agreed at the International Conference on the Conservation of the Living Resources of the Sea, hosted by FAO (Rome, 1955). The 1982 Convention provided that the best scientific evidence shall be taken into account by the coastal State when designing and adopting management and conservation measures in exclusive economic zones (Article 61). For the high seas, this Convention provides that measures are designed on such scientific evidence (Article 119). More recently, the General Assembly Resolution 44/225 recognized, in its preamble, that "*any regulatory measures ... should take account of the best scientific evidence available*". The 1982 Convention, however, does not define the evidence required in any quantitative manner.

Regarding the necessary amount of data, Cooke (1994) proposed that there be a relationship between the amount of data available and the level of catches allowed, indicating that a **minimum information requirement** be established, such as a recent estimate of the low end of the likely available biomass. This might sometimes be difficult to obtain without any fishing at all, although, for many resources, some rough estimate could be obtained through trawl or acoustic surveys. Cooke specifically proposed that "*permitted catches be lower when data are sparse than when data are plenty*" and stressed that this "*attaches a positive effective value to fisheries data and opens the way to data collection programmes financed by the users*".

Regarding the quality of the necessary data, the requirement that the evidence should be the best available implies that even poor evidence can be used in designing conservation measures provided it is recognized as the best available. The 1982 Convention does not provide any guidance on how to decide which is "*the best*" scientific information. Nor does it indicate how to operate in the absence of a scientific consensus, which it implicity assumes, or when no scientific information is available at all. Although the 1982 Convention does not foresee that an existing fishery could be closed if not enough scientific information is available, it does not impose a great burden to be discharged before the necessary conservation measures can be taken (Burke, 1991). One would assume therefore that, in such a case, the spirit of the Convention is that the missing scientific information should be urgently collected but this does not preclude measures being taken in the meantime. The concept of precaution would ensure that action is not deferred *sine die*.

Concern has been expressed that the adoption of the precautionary approach could imply that scientific facts to back up management decisions were no longer considered necessary. There is an obvious risk that, by referring to the concept of precaution, scientific objectivity could be less rigorously applied and that international dialogue could be negatively affected. It is hardly debatable, however, that when scientific data are available together with a monitoring and management system, the basic requirement of the 1982 Convention should prevail and decisions should be taken on that basis. It should also be clear that, in order to satisfy the requirement of the 1982 Convention for the best scientific evidence available, the information must be scientific(i.e., obtained and presented in an objective, verifiable and systematic manner)[12] and it does need to be made "available" to all concerned. This, in the context of straddling and highly migratory resources, requires the existence of effective international scientific cooperation and the elimination of non-reporting and misreporting.

In the absence of a scientific consensus, emergency action should, therefore, only be justified when there is the risk of severe and irreversible effects and the concept of precaution may be seen as filling the gaps in the 1982 Convention, preventing the absence of scientific data or consensus from opening a loophole leading to "laissez-faire"management and development strategies with damaging or irreversible consequences. In an international fishery management body, a State willing to invoke the need for a precautionary approach in order to promote exceptionally stringent management measures, would have to convince the other parties that exceptional conditions are met for its application, i.e., that there is indeed a high risk of severe and irreversible damage. Science should, as far as possible, demonstrate the existence and extent of risk through risk analysis. If the available information was considered insufficient to demonstrate objectively the risk, forced application of the concept of precaution could become counter-productive. It is recognized, however,that in such a case, the management authority would have to face "perceived risks", in the absence of objectively demonstrated ones as is often the case with global societal risks and a consensus will have to be achieved through a largely political process involving as much consultation, participation and transparency in decision-making as possible.

[12]This implies that the "traditional knowledge", the foundation and accuracy of which is largely unknown, be collected and assessed in order to eventually become part of the "scientific" basis for management

5.2 The Role of Statistical Methods

The 1982 Convention does not give any indications on how to determine which scientific evidence is the "best". General Assembly Resolution 44/225 required "*sound statistical analysis*" and this new terminology could be considered an attempt to clarify further the concept of "best evidence", equating it with "*statistically sound evidence*". The advantage of incorporating statistics into the concept is that it offers a way of using well-established mathematical techniques and tests to assess the probability that a certain action has had or may have a certain type of effect. It also forces scientists and decision-makers to recognize and measure explicitly the levels of uncertainty and the risks attached to these decisions. A research programme to monitor a fishery will use statistics to test, for instance, a null hypothesis (Ho) that the ongoing fishing, or planned increase in fishing effort or change in fishing strategy, will not drive (or has an acceptably low probability of driving) the reproductive capacity of the species below some pre-determined safe threshold level. Scientists must still agree on which type of statistical methods to use (parametric, non-parametric, geostatistics) and which test is most appropriate for a particular problem. Fisheries do not usually conform strictly to the requirements for unbiased application of conventional statistical methods and the reliability of many statistical tests might still be a matter for debate. As a consequence, obtaining a consensus on the "best statistical analysis" to use might not always be easy. In this respect, Peterman and M'Gonigle (1992) have stressed the potential contribution of Statistical Power Analysis to the issue. They remind us that *"statistical power is the probability that a given experiment or monitoring programme will detect a certain size of effect if it actually exists"*. Related to the example given above, it means that the statistical power measures the probability that the fishery monitoring programme will effectively detect the reduction of the reproductive capacity below the safe threshold level. Peterman and M'Gonigle suggest that the lower the statistical power of an experiment, the more precautionary the management response should be. In addition, it is clear that the best statistical methods can only lead to unreliable results if applied to unreliable data. It is, therefore, obvious that rigorous statistical methods should also be applied in data collection systems, particularly for collecting fisheries data.

5.3 The Burden of Proof

The "Proof"

The concept of "burden of proof" is often used in conventions and other texts referring to the precautionary approach. Considering the level of uncertainty which characterizes aquatic systems and socio-economic systems, it should be clear that absolute "proof" *stricto sensu* is hardly available. The concept, whether of an impact or of the absence of an impact, implies usually a level of certainty that is generally not reachable in fisheries research. In fisheries, the concept of "proof"could be related to the concept of "scientific evidence" established by the 1982 Convention on the Law of the Sea. The "burden of proof"could, therefore, be interpreted as the burden of providing the scientific evidence. It must be noted that just as there is no criteria in the 1982 Convention to define what information is "best", the references to the "burden of proof" do not provide any guidance as to the "standard of proof" (i.e., the criteria by which to judge whether a "proof" is acceptable). In this respect, the concept of scientific evidence has the advantage to specify that the evidence must be scientific, i.e., obtained and presented in an objective, verifiable and systematic manner.

The Burden

In conventional fishery management, the "burden of proof", i.e., the responsibility of providing the "best scientific evidence available" required by the 1982 Convention, has fallen traditionally on research and management institutions. It has been necessary for them to demonstrate, with the available data, that the stock could be (or had been) damaged, or that fisheries performance could be improved, before management measures could be imposed. In many instances, this approach has not been effective because fishery research lagged behind development and was not in a position to anticipate changes in techniques and practices. The principle of precautionary action provides a partial solution to this important and recurrent problem in requiring that action be taken even in the absence of "full scientific certainty" about the extent of the risk and the causal relationships. This is often associated with the proposal to "reverse the burden of proof", i.e., reverse the responsibility to provide the necessary evidence, implying that:

a. human actions should be assumed to be harmful to the resource unless proven otherwise, giving systematically to the resources the benefit of doubt, and

b. the responsibility to prove that human action is harmless or that the impacts are acceptable[13] lies on those who intend to derive benefits from the ecosystem and not on the management authority.

Proposition (a) may be taken as implying that any fishing technique, which has not been formally authorized, in a given fishery or management area, or for a particular species, is forbidden, a principle enshrined in the FAO International Code of Conduct for Responsible Fisheries. The requirement is related to the notion that an environmental impact assessment should be presented before a new technology or practice is introduced into an ecosystem. It is also related to the concept of prior consent or prior authorization (discussed below Section 6.2). Proposition (b) above, might be more easily implemented in an international agreement, when the party bearing the burden would be a flag State with research capacity. This proposition could, sometimes, be more difficult or impossible to implement at national level when the fishery sector is informal, financially and technically weak or poorly organized as in many developing countries coastal and small-scale fisheries, as well as in overfished fisheries where most of the initiative for corrective action (e.g., fisheries reconversion) starts from governmental initiative.

In most cases a simple Environment Impact Assessment (EIA) based on evidence available locally, or in similar fisheries elsewhere, could be sufficient to produce the evidence required(cf. Section 6.3). In the case of a completely new methodology or fishery (e.g., on a non-traditional species) a major difficulty in the implementation of the concept is that it will be difficult or impossible to forecast, with any degree of accuracy, the impact that the new fishery will have before it has started and some data have been collected. There is, therefore, a real risk that no new fishery could be developed because evidence of the absence of adverse impact cannot be given by those involved in the venture. A reasonable precautionary approach, in such a case, should lead to agreement for a pilot fishery large enough to collect data and build up the scientific evidence required, but small enough to ensure that no irreversible effect is likely[14] (cf. Section 6.4).

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[13]For a discussion on "acceptable" impacts, see Section 7.4

An example of application of the concept to international fisheries can be found in the UN General Assembly Resolution 44/225. This resolution recommended a total ban on large-scale driftnet fishing in the absence of scientific consensus on the likely long-term impact, implying that the prohibition of a disputed fishing technique is in order until its acceptability has been demonstrated. It stated that "*such a measure will not be imposed in a region or, if implemented, can be lifted, should effective conservation and management measures be taken based upon statistically sound analysis to be jointly made by concerned parties…*". This resolution reversed the conventional course of action. recommending immediate and drastic action (i.e., a total ban of the offending gear) on the basis of international concern assuming that driftnets had an undesirable impact on resources, until shown otherwise. It was agreed that such action could, in principle, be reversed should the joint scientific analysis lead to consensus on the effectiveness of management measures. The UNGA Resolution 44/225 gave no guidance or criteria on how to judge the quality or adequacy of the available evidence or the effectiveness of the management measures. The action was confirmed by General Assembly Resolution 46/215 of 20 December 1991, which called for action against this type of fishing on the basis that "*the international community [has] reviewed the best available scientific data and [has] failed to conclude that this practice has no adverse impact … and that … evidence has not demonstrated that the impact can be fully prevented*". Another example of reversal of the burden of proof can be found in Council Regulation 345/92 of the European Economic Community (EEC).

which regulated the use and the length of driftnets (limited to 2.5 km) in EEC waters. Article 9(a) granted a derogation until 31 December 1993 to some vessels for the use of longer gear, stating that "*The derogation shall expire on the above-mentioned date,unless the Council, acting by a qualified majority on a proposal from the Commission, decides to extend it in the light of scientific evidence showing the absence of any ecological risk linked thereto.*"

In addressing the issue of the burden of proof, the Technical Consultation on the Precautionary Approach to Capture Fisheries, held in Lysekil, Sweden, 6–13 June 1995 (FAO 1995), considered that adherence to the guidelines it produced, and particularly to the elements contained in its summary statement (Annex 6), would ensure and appropriate placement of the burden. In addition, the Technical Consultation recognized that the following elements would help clarifying further the issue:

- "*all fishing activities have environmental impacts and it is not appropriate to assume that these are negligible until proved otherwise;*
- *although the precautionary approach to fisheries may require cessation of fishing activities that have potentially serious adverse impacts, it does not imply that no fishing can take place until all potential impacts have been assessed and found to be negligible;*
- *the precautionary approach to fisheries requires that all fishing activities be subject to prior review and authorization; that a management plan be in place that clearly specifies management objectives and how impacts of fishing are to be assessed, monitored and addressed, and that specified interim management measures should apply to all fishing activities until such time as a management plan is in place, and*
- *the standard of proof to be used in decisions regarding authorization of fishing activities should be commensurate with the potential risk to the resource, while also taking into account the expected benefits of the activities*".

[14]The question is more complicated in the case of introductions of species and GMOs where there is no guarantee that the introduced elements could be safely eradicated once introduced, even on a pilot phase, and there is opposition, in this case to the concept of pilot experiments REF

5.4 Practical Guidelines

In order to support the effective implementation of a precautionary approach to fisheries management and development, fishery research needs to be adapted to the new requirements and should, in particular:

1. ensure that the "*lack of full scientific certainty shall be not used as a reason for postponing cost-effective measures to prevent environmental degradation*" (principle 15 of the Rio Declaration);
2. take into account the best scientific evidence available when designing and adopting management and conservation measures, in accordance with the provisions of the 1982 Convention;
3. require a minimum level of information to be made available for any fishery to start or continue;
4. make all necessary efforts to collect the required scientific information. For new fisheries, data collection should start with the fishery, including data on genetic and stock structures. For existing fisheries, data collection should start as soon as possible and any increase in effort should be preceded by a research or assessment programme;
5. ensure and require that information provided as a basis for management be "scientific" (i.e.,

obtained and presented in an objective, verifiable and systematic manner) and "available" to all concerned;

6. develop the effective international collaboration required to collect and jointly analyse the scientific information, particularly inthe case of trans-boundary, highly migratory or high seas resources;
7. take measures aiming at eliminating or reducing non-reporting and misreporting, *inter alia*, by ensuring that the fishery sector cooperates in data collection and is fully informed of the results and uncertainty in the assessment;
8. relate the allowance in terms of TACs, catch quotas, number of licences, etc. to the amount and quality of the available data, ensuring that permitted catches be lower when data are sparse rather than when data are plenty;
9. generalize the use of standard statistical procedure to judge the quality of the scientific evidence available and ensure that such information and the analysis therein is statistically sound;
10. improve statistical methodologies for assessing the biological and economic parameters, testing their sensitivity to uncertainties in the data used and systematically estimating bias and precision in the derived parameters. The sensitivity of models to uncertainties in their parameters and functional structure should also be tested;
11. assess the statistical power of the tests and methodologies used for comparing the relative "soundness" of the information available. The lower the statistical power of the assessment, the more precautionary the management measures;
12. develop standards of proof and agreed protocols for Environmental Impact Assessment, pilot projects and experimental management projects;
13. promote multidisciplinary research, including: (a) social and environmental sciences, and (b) research on management institutions and decision-making processes, because the availability of biological evidence alone has not prevented overfishing;
14. expand the range of fishery models (e.g. bio-economic, multi-species, ecosystem and behavioural models), taking into account: (a) environmental effects; (b) species and technological interactions, and (c) fishing communities' social behaviour;
15. systematically analyse various possible management options using the whole range of available models, showing: (a) the likely direction and magnitude of the biological, social and economic consequences, and (b) the related levels of uncertainty and the potential costs of the proposed action (risk assessment), and no action (*status quo* scenarios);
16. systematically analyse and highlight the most pessimistic scenarios[15], in situations of doubt and high risk of irreversible damage to the resource;
17. develop scientific guidelines and rules for multi-species and ecosystem management as a basis for agreement on acceptable degrees of disturbance;
18. agree on quantitative reference points and thresholds as well as on methods to establish them[16];
19. systematically quantify the risk associated with scientific advice at the various reference levels selected;
20. improve understanding of environmental impact, raising the awareness of fishermen to the possible impact on fisheries potential resulting from fisheries as well as from environmental

degradation caused by other industries, and

21. improve technological research on fishing gear and practices and their environmental impact.

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[15]For instance, models which assume strong dependence of recruitment on adult stock size and predict rapid collapse when effort develops beyond a critical level (such as the Gulland-Schaefer production model or the Ricker stock-recruitment model), should be used rather than models assuming no relation between stock and recruitment and high resilience of stocks to high fishing rates (such as the Fox production model or the Beverton and Holt yield-per-recruit and stock-recruitment models)

[16]For instance, if it is agreed that it is safe to exploit a resource at two thirds of its MSY, it will be necessary to agree on the reference data set and on the conventional model on which to base the calculations because the true value of 2/3 MSY, and of its corresponding level of effort, will never be exactly known and may vary according to the model used

6. IMPLICATIONS FOR TECHNOLOGY DEVELOPMENT AND TRANSFER

Fishing affects targeted stocks and associated species, reducing their abundance and spawning potential, changing size structure and species dominance or composition and modifying the trophic chain. These effects are "normal" in the sense that they result from the need to exploit fish, and must be addressed and kept at acceptable levels by management (see Section 7.4). Fishing also has side effects on the flora and fauna living in the exploited environment (birds, turtles, marine mammals, benthic communities, coral reefs, seagrass beds) as well as on the bottom itself (trawls and dredges). In addition, "ghost fishing" by lost or discarded driftnets or pots has been suspected and, in some instances, demonstrated. It is not by chance that the very first discussions, in FAO, on the concepts of responsible fisheries, focused on responsible "fishing", i.e., on responsible fishing gear and technology, before broadening the concept to cover also management, research, fish processing and trade and aquaculture.

An example of international concern is given by the reaction to the rapid expansion of the large-scale pelagic driftnet fishing (see Section 5.3). The problem has been apparently "solved" by a moratorium on all driftnets of more than 2.5 km in length, through heated debate and political wrestling, but Miles (1992) indicated that the application of the same flawed process and criteria to EEZ fisheries would lead to closing down of many of them[17]. Another example is the concern expressed regarding impacts on cetaceans off Ireland and Denmark (Schoon, 1994) by bottom gillnets of up to 7 miles long, used in coastal waters, for the last 15 years to catch bottom fish such as turbot, plaice and cod.

The following sections, which draw from the work of Boutet (1995), will address various ways in which the problem could be addressed in the context of a precautionary approach to fisheries, i.e., through the adoption of responsible fishery technology and practices, the establishment of technology lists, the adoption of Prior Informed Consent and Prior Consultation Procedures, the requirement for Environmental Impact Assessment and the implementation of pilot or experimental development projects.

6.1 Classification of Responsible Fishery Technology

In international environmental law, the precautionary principle is often associated with the requirement to use the "*best available technology*", an obvious parallel to "*best scientific evidence available*". This wording has sometimes been interpreted as requiring the technology which has the smallest environmental impact, regardless of the short-term socio-economic costs. This interpretation has, however, been questioned on the basis that such technology might not always be affordable by all countries and, in particular, by developing countries (GESAMP, 1986). General Assembly Resolution 44/228 of 22 December 1989 on UNCED referred instead to "*environmentally sound technology*", stressing the need for socio-economic constraints to be taken into account. The wording does not pretend to limit the choice to a single "best" or soundest technology and does not preclude, therefore, the use of many "sound" technologies together, depending on the socio-economic context of their introduction. The Cancun Declaration (Mexico, 1992) provides that "*States should promote the development and use of selective fishing gear and practices that minimize waste* *of catch of target species and minimize by-catch of non-target species*", focusing on only one of the challenges of responsible fishing.

[17]As a matter of fact, arguments similar to those used to request the closure of the large-scale pelagic driftnet fisheries were invoked to force the closure of the small-scale bottom gillnet fishery in California, showing both the potential and the danger of media-driven campaigns against fishing techniques

The development of typologies and classifications is usually the basis of a process of normalization or standardization of technology in view of its regulation. The basis of a classification in fisheries could be horizontal or vertical. A **vertical classification** would involve classifying gears according to their priorities with the aim to regulate their use. An **horizontal classification** would classify ecosystems and species assemblages, or parts of them, as a basis for the regulation of their use. In practice, both classifications would be required in order to develop flexible regulations taking into account the diversity of gears and ecological situations (and even socio-economic situations). The use of lists to classify chemical substances, techniques, species[18], weapons, etc. is fairly frequent. In environmental law, technologies are often catalogued on separate lists, the "colour" of which reflects the perceived degree of environmental friendliness. For instance:

"Black" or "Red" lists would identify technologies for which the likelihood of producing unacceptable impacts in most or all of their application.

"Grey" and "Orange" lists would identify technologies susceptible to produce potentially acceptable impacts in most of their applications but which should be used under some conditions and require a specific impact assessment before being introduced.

"White" or "Green" lists would identify those technologies believed to be harmless or producing only acceptable levels of impact and which could be introduced without a particular precautionary procedure.

The task is not easy. One problem is in deciding whether one would catalogue gear, aid to navigation and detection (which increase fishing power) or fishing practice, or both. Another problem is to decide on the objective criteria for the classification. If responsible fisheries is the objective, gear should be classified according to related criteria (referring for instance to selectivity and by-catch rate; impact on bottom, navigation and environment in general; relative energy consumption; biodegradability; difficulty to control and monitor, etc.). For fishing gear, the classification of a technology will depend, *inter alia,* on the type of habitat. Heavy trawls may be considered"green" on deep muddy grounds but "red" in shallow estuaries and coastal zones or coral reefs. Artificial reefs might be on a grey or orange list because their impact on coastal habitat is long-lasting and, if made of derelict material, they may contaminate the environment.

This list approach has been indirectly applied to fisheries by reference to the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979). The Convention gives, in its Annex IV, a list of non-selective gear to be banned, which includes all nets. Although it had been designed for migratory birds, the list has been referred to, in Italy, in connection with the banning of large-scale pelagic driftnet fishery. The importance of nets in fisheries and their contribution to the livelihood of small-scale fishermen and indigenous people illustrates the need for careful consideration before referring to lists contained in non-fishery agreements and before elaborating specific lists for fishery technology.

[18]CITES, has recorded species in lists, according to their status, and specific measures correspond to each list

Considering that, in fisheries, the concept of responsible fishing is well defined and that a Code of Conduct for Responsible Fishing has been prepared and will be adopted, it may be of value to refer to the requirement for "**Responsible Fishery Technology**" (including capture and post-capture technology) as defined in the Code and its different guidelines. Responsible technology will have to be used in all areas of fisheries, including capture, land-based or sea-based processing and distribution. As a consequence, although some general guidelines can be given, based on known characteristics of types of resources and technology, the most responsible mix of technologies to be used in a particular fishery will have to be agreed on a case-by-case basis with explicit reference to the agreed management reference points and acceptable levels of impact agreed for that fishery. The implication is that technology lists could not be for general application and would have to be established locally, at regional and national level.

One must recognize, however, that lists of prohibited gears and practices exists in most national legislations and that these are frequently ignored. Examples are: fishing with dynamite or poison, fishing with scuba-diving equipment, use of obstructive shaffers on trawls cod-ends, use of driftnets, of small-meshed beach-seines, etc. The efficiency of technology classifications and list of authorized gears is therefore strongly dependant on the capacity of monitoring and enforcement.

Care would also have to be taken to ensure that the use of gear lists does not lead to freezing the evolution of technology and that mechanisms exist (including the use of pilot projects) to allow this evolution while keeping the overall fishing mortality under control. Fitzpatrick (1995) also stresses that, in many instances, the technology necessary for fishermen safety, also improves the fishermen's ability to locate and catch fish and, therefore, contributes to overfishing. Such technology, often required by international conventions on safety on board of fishing vessels cannot however, in most instances, be removed from the vessel. The implication is that fleet size may have to be reduced when fishermen safety is improved, in order to stabilize fishing mortalities.

Moreover, a "better" technology might be theoretically available on the market but in effect not accessible to some countries because of its cost or its sophistication and, in many instances, the generalization of the use of responsible technology will require an improvement in international cooperation in technology transfer, as underscored in Agenda 21[19].

6.2 Prior Informed Consent (PIC) and Prior Consultation Procedures (PCPs)

For dangerous polluting industries, reference has often been made to Prior Informed Consent (PIC) and Prior Consultation Procedures (PCPs). The practical significance of the procedures involved is that, before introducing a dangerous technology or any new technology in a controlled or sensitive area, the proponent must produce a substantial amount of information about the technology to be introduced and its potential impact and, eventually, obtain the consent of the State or the managing authorities. If the introduction is agreed, a number of specific measures are usually foreseen such as limiting the scale of the initial project, special monitoring and reporting requirements, etc.

These practices are rare in fisheries. An example can be found in the ICES/EIFAC Code of Practice to Reduce the Risk of Adverse Effects Arising from Introduction and Transfers of Marine Species including the Release of Genetically Modified Organisms (Turner, 1988) which has been adopted by the International Council for the Exploration of the Sea (ICES) and the European Inland Fishery and Advisory Commission (EIFAC) of FAO. The ICES/EIFAC Code foresees that "*Member countries contemplating any new introduction should be requested to present to the Council, at an early stage, information on the species, stage in the life cycle, area of origin, proposed plan of introduction and objectives, with such information on its habitat, epifauna, associated organisms, potential competitors with species in the new environment, genetic implications, etc., as is available. The Council should then consider the possible outcome of the introduction, and offer advice on the acceptability of the choice.*"

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[19] The successful efforts made by the Inter-American Tropical Tuna Commission in the Eastern Central Pacific area to train crews of the region in effectively avoiding by-catches of dolphins through the use of appropriate technology, is a good example of what can be achieved in this respect

The European Directive 90–220 on dissemination of genetically modified organisms intends to frame the development of biotechnologies in Europe and address the "genetic risk" potentially represented by these technologies, which are of great potential interest also for fisheries (EEC, 1990). Hermitte and Noiville (1993) stress the precautionary character of the Directive, which applies the precautionary principle, not to a single product (chemical substance), or to a specific problem (ozone hole), but to a whole new mode of production, even before any incident has been registered. The Directive recognizes that a new production mode carries with it significant social (societal) changes and potential risks and, contrary to what has happened in industrial development since the 18th century, attempts to foresee and limit the negative impacts of this new technology. It reverses the traditional industrial culture and freedom to undertake, produce and sell as long as a danger has not been proven.

In exclusive economic zone fisheries, where effective effort controls have been established, there is often a requirement to obtain prior consent from the management authority before a new vessel is ordered or even before the banks are approached for a loan for this purpose. A similar approach might be used for some particularly efficient and potentially dangerous technologies and/or for particularly vulnerable resources or fragile ecosystems when severe, irreversible effects are possible. In a regional or international context, Prior Informed Consent of the competent regional management organization or arrangement would be required before introducing a new methodology. The procedure would be better accepted if the new technology was patented, limiting the risk that the benefits to the "discoverer" could be jeopardized in the process. In such an international or regional mechanism, a State willing to introduce a new technique would be requested to present a report, comparable to an **Environmental Impact Assessment** (see section on EIA below). Such an assessment would address potential effects on the target species, on associated species which might be targets for other fisheries in the area or food items for such target species and on the environment.

It has been mentioned that an overly stringent application of the precautionary principle might be contrary to the willingness and need to ensure technological progress. Hermitte and Noiville (1993), however, indicate that the prior authorization process, the resulting direct involvement of industry in promotion of data collection and research, and the transparency resulting from the public information and participation would, on the contrary, contribute to dissipate the fears towards technology and, indeed, limit irrational reactions to innovative technologies. One major benefit from a prior authorization process, beyond the limitations of risk, would be in the mandatory delivery, by industry, its scientists and experts, and at industry's expense, of information on ecosystem functioning and technological impacts and of the resulting "memory" that Hermitte and Noiville call "*scientific jurisprudence*". These authors state that the acceptance of the procedures by scientists and industry would be a sign of good faith given to a more and more suspicious, sceptical and unforgiving society and that these procedures may in fact be the only way to avoid irrational bans on research and development avenues and the development of "wild" experiments.

The administrative burden imposed by prior authorization procedures could be overwhelming and, at least in fisheries, there would be obvious advantages if the procedure could remain exceptional. The scope of application (and unnecessary burden) of the measure could be reduced using the concepts of "*familiarity*" and "*previously acquired experience*" (Hermitte and Noiville, 1993) or referring to "*evidentiary presumptions*" (Bodansky, 1991) to take into account available knowledge obtained elsewhere in similar or sufficiently comparable conditions, to reduce the amount of uncertainty and presumption of risk. In order to avoid repeating the impact assessment of similar technologies on similar species and ecosystems, it would be useful to develop a general typology of fishery technologies, gears and practices and their potential impact, leading to a general impact-oriented classification of gear/species/ecosystems interactions, to be used as a guide, by management authorities, at regional or national level, to develop local gear and technology classifications based on local characteristics of the resources and the environment[20](see also Section 6.1). The special monitoring and reporting procedures could then be limited to new technology/species/ecosystem combinations and to existing technologies recognized as unacceptable in the long term and for which phasing out might have been decided (and for which interim reports could be requested during the phasing out period).

In the case of high seas areas not covered by any specific international agreement, there would be no competent authority to which the request for prior consent could be made. In addition, there would also be no monitoring or enforcement system in place, making it impossible to detect the introduction of harmful techniques and to measure impact. This is a case where the legal responsibilities of the flag States would need to be clearly determined, especially if the flag State registers all vessels authorized to fish in the high seas as provided for in the 1993 Agreement on the Promotion of Compliance with Conservation and Management Measures by Fishing Vessels in the High Seas.

6.3 Environmental Impact Assessment (EIA)

Impact assessment is a major instrument of environmental law, which conditions the beginning of an activity or the deployment of a technology to an assessment of the consequences on the environment. Generally, an EIA provides not only an assessment of the impacts but also proposals aiming at mitigating the impact if necessary. As it would not be practical to condition all fishing activities to EIA it might be necessary to define the conditions under which an EIA might be necessary. This could be done: (a) through preliminary studies, on a case-by-case basis, and (b) through an overall identification and cataloguing of the technology/resource combination requiring such approach (see above).

The EIA seems to have been rarely used in fisheries (except possibly in aquaculture and for species introductions). If generally adopted, the EIA procedure would be part of the legal procedure leading to the granting of a fishing right or license for a particular fishing activity by an authority with the legal competence required to authorize or deny such a right. This authority would define the requirements and specifications of the EIA. An EIA procedure would require the establishment of a system to control the conditions of the assessment, its relevance and objectivity. This implies that:

[20]This comparative approach is not really new in fisheries, but the process of fisheries law development, in developing countries, to which FAO contributes actively, involves already a lot of transfer of experience from area to area. The approach could however be formalized and more systematically applied

- the proponent would be allowed to appeal if the procedure imposed is not in line with the established specifications, or if the decision of the authority does not appear in line with the conclusions of the EIA;
- the authority, which would decide on the acceptability or otherwise of a new technology or practice, would have to be able to oversee the whole EIA process to guarantee to all users the quality and reliability of the assessment;
- the procedure should be transparent to all users who receive information on request and on the EIA process. It might be necessary to organize a debate on the issue to have all views. It would be essential to ensure that the authority keeps the necessary prerogative to ultimately decide;
- the other users (and in particular the users of a different technology on the same resource) should have the possibility to appeal on a decision if it appears to be in contradiction with the conclusions of the EIA, and
- as a last resort, recourse to tribunals (in EEZs), or to dispute settlement mechanisms (in international fisheries), should always be possible if one of the parties in the EIA process believes that its interests are being unduly affected.

There should be some relation between the cost of the EIA and the cost of the potential negative consequences of the proposed development and its potential benefits. There should also be some relation between the cost of the foreseen investment and the cost of the EIA. In some instances, participation by the authority or State in the EIA might be worthwhile and equitable, particularly when the technology being considered has general potential application. State participation in the EIA would certainly be necessary for coastal and small-scale fisheries, particularly in developing countries (see Section 5.3 on the burden of proof).

6.4 Pilot Projects

Despite their relatively smaller size, fishery pilot projects can be considered a s"full-scale" experimentations, only limited in duration and geographical extension. They could be a useful way to implement a precautionary approach to fishery development provided that specific rules are adopted for their conduct, data collection, and analysis. They have the advantage of being less theoretical than EIAs, and therefore more convincing, while limiting the probability of inadvertently damaging the resource, and allowing a more realistic approach to socio-economic impacts than otherwise possible. Allowing for a phased approach to application of technology at a larger scale, they represent a practical tool for implementation of a "*stepwise decision making*" and "*progressive deconfinement*" of a new technology, advisable to situations of high uncertainty (Hourcade, 1994). Pilot projects have been extensively used in the past, including in FAO fishery development programmes, to demonstrate the technical and economic feasibility of a development or management measures. An experimental fishery has been developed for instance on *Paralomis spinosissima* crab fishery in the Antarctic (CCAMLR area) (Watters, 1993) and the concept is one with which industry is generally familiar. A basic assumption behind the concept of pilot projects is that the large-scale implementation of the technology is a simple extrapolation of the pilot scale. This may not always be the case and a significant involvement of basic and applied sciences is necessary for improving the protocol and specification of traditional pilot projects allowing them to become also useful and reliable elements of a precautionary fishery development policy. Another implicit assumption is that all traces of the experiment can be eliminated if the pilot-scale project indicates that the tested approach or technology results in unacceptable consequences. This may not always be true and explains the opposition of some scientists to the concept, particularly in cases where the consequences detected in the pilot project are not reversible (as may be the case with introduction of GMOs). The implication is that only part of the cost of a pilot project could be considered as additional charge required for precaution. Most of it could, in many cases, be considered as normal pre-investment expenses.

The management authority should have enough latitude to impose, to a proponent of a new technology or new fishery, the type of experimentation considered most appropriate. A contractual agreement between the authority and the proponent would improve the probability that the rights of the "discoverer" of a technology or a stock are respected.

The pilot project goes beyond the EIA in the sense that real development will occur, even though at small scale. In some cases, the authority itself could be (and often has been, in the past) the promoter of the initiative. In some cases, both an EIA and a pilot project might be required and executed sequentially when the EIA is not totally negative but some aspects may not be addressed without experimentation.

6.5 Practical Guidelines

A precautionary approach to fisheries should ensure the use of responsible fishery technology in all sub-sectors, including capture, land-based or sea-based processing and distribution and ensure that:

1. technology, formally recognized as "responsible", is compatible with long-term resource conservation, minimized by-catch of endangered species and discards, as well as other non-acceptable impact;

2. the mix of responsible technologies (and practices), to be used in a particular fishery, is agreed on a case-by-case basis with explicit reference to the management reference points and acceptable levels of impact agreed for that fishery. This mix should be compatible both with local conditions for sustainability and socio-economic conditions of the operators;

3. recommended technologies are easily available on the market and affordable for developing countries and that their transfer is promoted through international cooperation;

4. criteria for the selection or determination of responsible technology include local biological and

environmental conditions and socio-economic constraints;

5. selection or determination of responsible technology is based on an objective assessment of the actual or likely impacts and of the risks involved, for the resources, associated species and, in the long term, for the fishing community, taking into account the type of resources, ecosystem characteristics, and habitat;

6. technological requirements are defined with a view to maintaining (or reducing) the accidental effects of capture and post-capture fishery activities within pre-defined acceptable (tolerable) levels, allowing general application by all countries or parties involved;

7. States and management organizations and mechanisms undertake to list the fishery technology used or potentially usable, the "colour" of which would reflect the perceived degree of environmental friendliness;

8. before introducing a new technology in a controlled or sensitive area, on a low-resilience or particularly vulnerable species, the proponent is asked to produce a sufficient amount of information about the technology to be introduced and its potential impact and that the prior consent of the other users is required when appropriate;

9. if the introduction of a new technology is agreed, a number of specific measures should be foreseen such as limiting the scale of the initial project, special monitoring and reporting requirements, etc.;

10. when adopting PIC or PCPs, States or regional management, organization or arrangements should ensure that the potential rights (interests) of the inventor of the resource or of the technology can be protected;

11. request for the introduction of new techniques be supported by documentation amounting to an EIA identifying potential effects on the target species, and on associated species, which might be targets for other fisheries in the area or food items for such target species;

12. PIC and PCPs procedures should remain exceptional in order to reduce the administrative burden imposed to fishermen, and

13. special monitoring and reporting procedures should also be used for activities recognized as unacceptable in the long term and for which phasing out has been decided. Interim reports could be requested during the phasing out period.

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More details

THE PRECAUTIONARY APPROACH TO FISHERIES AND ITS IMPLICATIONS FOR FISHERY RESEARCH, TECHNOLOGY AND MANAGEMENT: AND UPDATED REVIEW (Continued)

7. IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

The imperfections in the fisheries management system, including uncertainties in management objectives, fishery and biological data, environmental oscillations, stock assessment methods, economic parameters, management advice, management measures and fishermen's behaviour have been recognized long ago (Larkin, 1972; Gulland, 1983). Gulland stressed the fact that "*imperfections that exist in all parts of the system...should not be an excuse for postponing action until matters are improved*" and that management action should be modified "*recognizing these imperfections and learning to live with them rather than attempting to eliminate them*". It is easy to recognize the precautionary approach in this 12 year old prescription to (a) recognize and accept uncertainty; (b) not delay action until more is known, and (c) learn to live with incomplete information. The solutions offered included, raising awareness on uncertainties and developing opportunism, flexibility and adaptation in management and development. These and other precautionary measures for fisheries management, have long been advocated as a means to avoid crises and higher costs to society (Walters and Hilborn, 1978). They have not often been applied in practice because more attention has been paid to short-term costs while long-term benefits have not been properly valued. Crisis management is unlikely to offer sustainable solutions to the problems encountered by fisheries.

Risk is unavoidable when deciding on harvest levels aiming at a range of conservation, social and economic (and political) objectives (Shotton, 1994). In such situations, decisions should be consistent with the theory of rational choice but the uncertainties on the data and models, as well as the differences and changes in the various users' preferences, make it impossible to define any optimum to be used as a single, resultant, management target. As a consequence, it is necessary to reflect the targets and constraints (both biological and economic) as "Reference Points", as landmarks which flag desirable or critical states of the known components of the system and which can be used to determine and influence the "position" of the fishery in relation to the multi-dimensional environment they materialize.

What is new in the modern requirement for precaution is not so much the sort of management measures that are suggested but the fact that they would be automatically enforced, with no exceptions, and that they should be implemented as soon as a serious and potentially irreversible effect is detected (Hey, 1992). In recent years, the major impulses towards precaution have been associated with crises. The stand taken by FAO (similar to that taken by IUCN (Cooke, (1994); see Section 3.2), is that a progressive but systematic and decisive shift towards more risk-averse exploitation and management regimes is preferable, for all users, to the present combination of a general "laisser-faire" policy with a few mediatic bans and with significant negative socio-economic impacts. The problem is, therefore, one of promoting effective caution in fisheries to the point where the risk of an irreversible impact on the environment and resources (and ultimately on the fishing communities) will be reduced below the level which would call for drastic measures with potentially irreversible damage to the fishery sector and the coastal communities. This could be achieved by exerting caution systematically, at all levels of the management process, to reduce substantially the probability of errors and the level of potential damage.

It must be realized, however, that extreme interpretations of the concept of precaution, which would lead to unnecessarily stringent and costly measures, could rapidly become counter-productive by deterring fishery authorities from using the concept as widely as possible.

It is often supposed that preventive (or proactive) approaches to management are more precautionary than reactive ones because they anticipate unwanted events through knowledge of the system. According to Boelaert-Suominen and Cullinan (1994), the principle of preventive action is based on "*the recognition (or assumption) that it is cheaper, safer, and more desirable (in the long term) to prevent environmental harm than to rectify it later, if indeed this is feasible at all*" (comments between brackets added by the writer). A strong and unwarranted assumption behind the principle of preventive action, however, is that there is enough knowledge to allow such events to be reliably anticipated and avoided. Unfortunately, as shown in Section 4, fishery systems are not fully predictable and errors are always likely. As a consequence, a precautionary management strategy would need both sufficient foresight to avoid predictable problems, and enough reactive (corrective) capacity, flexibility and adaptability to ensure a safe "trial-and-error" process, as knowledge about how the system works is collected (stepwise decision-making). In this respect, the importance of feed-back, adaptive probing strategies, and learning, for the improvement of management regimes, have been stressed *inter alia* by Walters and Hilborn (1976), Walters (1981, 1986), Parma and Deriso (1990), Hilborn (1994) as well as Hilborn and Smith (1995). In theory, probing should provide the optimal solution but Shane and Peterman (in press) provide a "Bayes equivalent" approach which should give a close approximation of the optimal strategy.

Because of uncertainty, it is not prudent for management to rely on deterministic pseudo-quantitative reference points of dubious precision for a target-based management (e.g., a management regime based on deterministic targets such as TACs and quotas). Precautionary management strategies would recognize the uncertainties in the data and promote adaptability and flexibility through appropriate institutions and decision-making processes, according priority attention to the biological limits of the resource. These strategies would rely not only on expert advice but also on effective people's participation. In case of doubt, decisions rules should "err on the safe side" having due regard to the risk for the resource and to the social and economic consequences in both the long and short term. A precautionary approach to fisheries management implies agreement on action to be taken to avoid a crisis as well as action required if such a crisis occurs unexpectedly. Agreement on such action, at national or international level, implies the existence of agreed standards, rules, reference points, critical thresholds and other criteria as well as consensus on acceptable levels of impact. These concepts will be examined in detail below.

7.1 Acceptable Impacts

There is no doubt that fisheries have an impact on the ecosystem, reducing species abundance and reproductive capacity, possibly affecting habitats and genetic diversity. Some species might be endangered, especially when fisheries, natural variability and environmental degradation by other industries combine their effects. An impact on the resource base cannot be totally avoided if fisheries are to produce a significant contribution to human food and development. However, the biological effects of fishery activities are usually reversible and experience has shown that trends in biomass and species composition can be largely reversed when fishing effort is curtailed or fisheries are closed, even though rehabilitation may take some time and the characteristics of the "rehabilitated" system may not be accurately predicted[21]. Degraded habitats may require particularly long recovery times and higher rehabilitation costs.

If development and benefits are to be obtained from fish resources, some level of impact has to be accepted and a zero-impact strategy would be impossible to implement in practice. It would therefore be necessary to: (a) identify and forecast fishery effects (and risks) accurately enough; (b) agree on acceptable levels of impact (and risk), and (c) develop management structures capable of maintaining fisheries within these levels. The wide use of such subjective terms as "*detrimental*", "*harmful*" and "*unacceptable*" to qualify unwanted impacts in expressions of the need for precaution is not very conducive to consensus and more efforts are required to specifically identify (preferably, by species and by region) what constitutes a risk and what risk is acceptable or not.

An **acceptable impact** could be defined as a negative, or potentially negative, alteration of the exploited natural system, resulting from human activities (i.e., fisheries and other impacting industries), the level and nature of which is considered as representing a low risk for the resource, system productivity, or biodiversity, on the basis of the available knowledge and level of uncertainty. Such a definition implies that: (a) the risk has been assessed using the best available evidence by all parties concerned, which agreed to it, in the light of the objectives stated for the resource, and (b) the impact will never be fully accepted (in the sense of definitely approved) but it will be kept continually under review and a decision about its acceptability eventually modified as knowledge progresses. The concept of acceptable impact may be related to that of **assimilative capacity**. This capacity, which has generated considerable debate amongst those concerned with environmental protection (Hey, 1992), has been defined as "*a property of the environment which measures its ability to accommodate a particular activity or rate of activity without unacceptable impacts*" (GESAMP, 1990). It assumes that nature might be able to absorb a certain quantity of contaminants (e.g., effluents from urban concentrations, radioactive waste, heavy metals and other causes of dramatic and potentially non-reversible impacts) without significant effect. The debate and opposition to the concept stemmed *inter alia* from: (a) opposition to the idea that oceans could legally be used for dumping, and (b) difficulty of determining objectively and agreeing on the evidence of innocuity or harmfulness of small concentrations of contaminants.

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[21] The introduction of exotic species and genetically modified organisms may be the most notable and serious exception to this observation as it is generally impossible to remove species (and certainly genes) from the ecosystem once successfully introduced

In fisheries, however, the problem is different. Fishery resources do possess an assimilative capacity in terms of the fishing mortality they can withstand while still conserving most of their resilience or capacity to return to their original state once the fishery-induced stress is removed[22]. In a way, the concept of Maximum Sustainable Yield, enshrined in the 1982 Convention, could be considered a reference point corresponding to the "maximum assimilative capacity" of a stock in terms of fishing stress, i.e., a level of stress beyond which fisheries should not be allowed to go and, perhaps, not even to approach (see Section 7.2 on MSY as a reference point). The situation becomes more complex when considering the assimilative capacity of a multi-species resource or an ecosystem for which no means of measurement is yet available.

The degree of acceptability of impacts (or risks) will be determined, *inter alia*, in terms of risk-benefit trade-offs with proper weighting given to long-term societal needs and value of natural assets. This requires research capacity to separate the effects of "natural" year-to-year fluctuations and the impacts of fishing from anthropogenic degradation, including global climate change. It requires the development of an effective enforcement capacity to ensure that such levels will be respected. Finally, it may also require the establishment of "**safety net arrangements**" (e.g., in terms of insurance, compensation, etc.) to protect the users from hazardous occurrences.

There is no scientific criteria to determine objectively what is acceptable to society[23]. It is likely, however, that what may be acceptable to some countries or user-groups may not be acceptable to others (an argument developed by Dommen, 1993), and the relevance and importance of traditions and culture in this respect should not be underestimated. One of the important prerequisites for the effects of fishing to be acceptable to society could be that they should be **reversible**[24] if the fishing pressure is reduced or suppressed. Referring specifically to ecosystems, Holling (1994) stressed that "*temporary erosion of any one (of the sources of renewal capacity) might be bearable as long as recovery occurs within the critical time unit of one human generation. But continued erosion of even one (of these sources) eventually reaches the point where it cannot be reversed by normal internal recovery*".

Decisions on what impact could or could not be allowed are comparatively easy when risks are known and extremely high. Proposals to prohibit, even without any scientific background, the use of explosives to fish (say, in the high seas) would probably not meet with much international opposition because harmful fisheries techniques (e.g., dynamite and poison) are normally banned by national fisheries legislation. However, deciding whether a 5% by-catch of sharks in a long-line tuna fishery (or whether a 10% probability to drive a stock below its theoretical biological safe limits) is acceptable would require more careful consideration and debate. Science should provide the methods needed to forecast and measure the impacts, as well as objective criteria on the basis of which agreements can be reached. The difficulty in this regard will not be less than in other scientific mandates (e.g., that of determining MSY) and we should expect considerable scientific argument on the type of impact one might expect and on the level of certainty with which it can be determined.

[22]Except in the case of serious damage to the habitat, introduced species and GMOs

[23]Even though alternatives and their consequences (including for society) can be scientifically analysed and transitory agreements might be reached on their basis

[24]It has already been mentioned that this requirement was particularly critical in the case of introductions of species and GMOs

The degree of acceptability of any impact will only be established after intense negotiations between the parties concerned. These are unlikely to proceed easily or rationally if undertaken in a context of crisis. It is, therefore, advisable to integrate negotiations on impact into the management process before stocks are damaged and before potential socio-economic problems reach an overwhelming level. Cooke (1994) proposes, for instance, that when information to set a full-fledged management system is lacking, precautionary exploitation rates could be limited to 1% of the original biomass estimate. He argues, rightly, that this rate might still be too high for some very long-lived species. One could argue, however, that such a rate would be extremely low and hardly justifiable for short-lived tropical species where sustainable annual catches can be equal or higher than standing stock biomass and might sustainably be about 30–50% of the virgin stock biomass. Returning to the old approximative rule that the fishing mortality at MSY is close to natural mortality (Gulland, 1971) and while recognizing its shortcomings, one could nonetheless suggest a less arbitrary and more flexible precautionary rate of exploitation. One could, for instance, decide that precautionary exploitation rates should never approach natural mortality rates (if only because catching MSY is not desirable) and be limited to, say, 25% of these levels. For example, it could be decided that the precautionary level of fishing mortality in absence of data, F_{prec}, should never be higher than 25% of the natural mortality rate, leading to catches below 1% of the biomass per year for very long-lived animals, but well above 25% for others, with equivalent degrees of precaution.

7.2 Management Principles and Decision Rules

Once agreement has been reached on what risk and what levels of impact are acceptable, one of the major tasks for research and management is to develop agreement on standards, rules, reference points and critical thresholds by reference to which decisions will be made to meet the selected management objectives and the requirements of the 1982 Convention, UNCED Agenda 21 and the FAO Code of Conduct. Over-restrictive rules (e.g., rules implying socio-economic consequences without proportion to the risks involved) or recommended without a clear understanding of their practical implications, are not likely to lead to the level of consensus required for the wide application of a precautionary approach required in UNCED Principle 15.

Because of the universality of conservation principles, precautionary management rules need to be established for all resources whether in EEZs or in the high seas. Because of the transboundary nature of many high seas resources, straddling stocks and highly migratory species, precaution should be applied across the entire area of distribution of the stock. This implies that coherent precautionary management regimes should be put in place, taking into account the geographical location of critical life phases (e.g., nursery, feeding or spawning areas) and ensuring that the measures taken inside the EEZs, and outside them, are coherent and are, overall, conducive to stock sustainability at safe levels of abundance. The following list gives some examples of principles or decision rules that have been proposed in the literature with a view to illustrating both the need for them and the difficulty of defining them in realistic terms:

1. fisheries should not result in the decrease of any population of marine species below a level close to that which ensures the greatest net annual increment of biomass;
2. fisheries should not catch amounts of either target or non-target species that will result in significant changes in the relationship among any of the key components of the marine ecosystem of which they are part;
3. the mortality inflicted on any target or non-target species is unacceptable if it exceeds the level that would, when combined with other sources of mortality, result in a total level that is not sustainable by the population in the long term;
4. fish management authorities should set target species catch levels in accordance with the requirement that fishing does not exceed ecologically sustainable levels for both target and non-target species;
5. fisheries management should take into account the combined stresses imposed by fishing, habitat loss and destruction, point and non-point sources of pollution, climate change, ozone level changes and other environmental and human impacts, and
6. fishery management should preserve the evolutionary potential of aquatic species.

The first principle implies that populations should not fall below the level of abundance corresponding to MSY, where their annual rate of biological production (turnover) is the highest. This is in line with the 1982 Convention requirements. It has been repeatedly shown, however, that it is often inadvisable to try to extract the MSY from a resource. Moreover, for multi-species fisheries, this principle would require that all species be exploited below their MSY abundance and, therefore, that the overall level of exploitation be fixed at the lowest level required by the species with the lowest resilience, reducing drastically the utility of the resource[25].

The second principle, which rightly aims at preserving the qualitative parameters and fundamental integrity of the ecosystem mechanism, implies that fishing will not "significantly" disturb the food chain (an unreasonable assumption), without guidance on how to judge whether an observed or potential disturbance is significant. Moreover, fishing all species at MSY, if at all possible, would lead, in practice, to applying different fishing mortalities to different species and this would lead to a change in relative abundance of species, affecting the food chain. As a consequence, the second principle may be difficult to implement in many fisheries and may not even be always consistent with the first.

The third and fourth principles require that all sources of mortality are taken into account when assessing fisheries impact. These would include natural mortality as well as direct and indirect fishing mortalities (through by-catch, drop-out, damage, ghost-fishing, etc.). In practice, this principle implies also that mortalities imposed by non-fishery users (e.g., through environmental degradation) should also be taken into account. A very demanding task indeed, in most cases beyond the present capacity of research systems, even in the developed world. Assuming that the task implied by the third principle is feasible, a problem remains with the vagueness of the term "sustainable" in the formulations. In theory, fisheries are "sustainable" at various levels of stock abundance and rates of harvesting, but these are not equivalent in terms of risk of recruitment collapse. Surplus production models, on which the concept of MSY is based, assume that natural renewable resources are "sustainable" (i.e., able to regenerate themselves year after year) at various levels of abundance depending on the level of harvest (Figure 1). A stock can in theory reproduce itself, and be considered sustainable, at high (virgin state), medium (MSY level) and even low levels of abundance, except for some species such as marine mammals and sharks. However, as stocks are fished down, their variability and the risk of collapse increases and it should be clear that all levels of theoretical "sustainability" are not equivalent in terms of risk for the resource. To be of practical use in fishery management, the concept of sustainability needs to be combined with the notion of risk for the resource and consequently to the fishing communities.

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[25]In a typical Mediterranean multi-species trawl fishery, where long-lived bottom species (e.g., seabream and red mullet) are targeted together with short-lived pelagics (e.g., sardine), this would imply fishing sardine well below the possible level of harvest in order to comply with the guidelines for seabream and mullet. The problem has been recognized in the report of the FAO Expert Consultation on Large-Scale Pelagic Driftnet Fishing (Rome, 1990)

The fifth principle, which in itself is perfectly laudable, has been reproduced only to illustrate the difficulty in practical implementation of some prescriptions. It is clear that the scientific data necessary to understand and forecast the impacts of all the sources of stress listed in the principle, some of which are still in the very early stage of study, are not available. As a consequence, they cannot be "taken into account". The point, however, that all stresses need to be addressed, including those imposed by non-fishing or related to natural fluctuations, is well taken and has been underlined in the FAO Code of Conduct.

The sixth principle would imply that fishing should only be allowed in a way which would not affect the ability of an exploited population to respond and adapt to natural and anthropocentric perturbations (including by fishing) on the population or its environment. This is a commendable proposal considering our uncertainty, on the value of specific genes and genetic variations, on the number of sub-populations necessary for ensuring stock viability in all conditions and on how fishing affects genetic resources. To comply with the proposal despite all uncertainties, however, management would actually have to aim at maintaining all the genes and genotypes present in the virgin stock. Since genetic variation is directly related to population size, such a management scenario would not allow any reduction of the population size at all and, therefore, any fishing at all. A proposal unlikely to generate consensus.

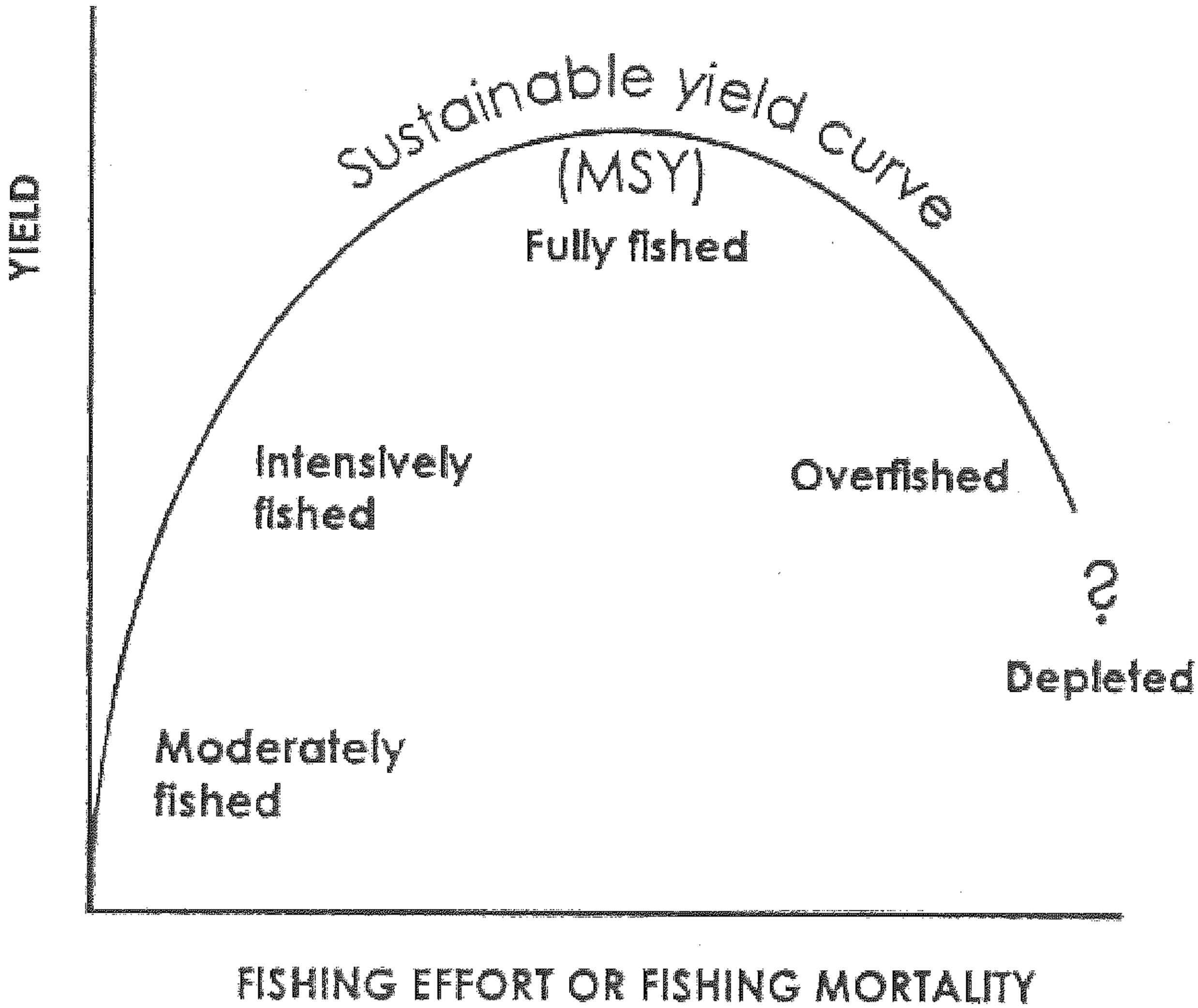

Figure 1: Relationship between fishing mortality (or effort) and sustainable yield.

7.3 Precaution and Management Reference Points

Reference points have always been used in management, explicitly or implicitly, and are not a particular characteristic of the precautionary approach to fisheries. Precaution will relate to the choice of reference points (and their resource-related properties) and to the way in which they are used.

A management reference point is "*an estimated value derived from an agreed scientific procedure and an agreed model to which corresponds a state of the resource and of the fishery and which can be used as a guide for fisheries management*"[26]. This definition stresses the fact that reference points are conventional constructions based on the knowledge and often on a model available at the time of their adoption. As a consequence, they are meaningful only with a reference to the underlying theory and model, method and data used for their estimation as well as species to which it applies. The consequence is that reference points should be re-assessed periodically as new data is collected and as new understandings or methods become available, there would be great danger of "chiselling them in marble" as was done for MSY in the 1982 Convention. In the paper prepared by FAO for the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, (FAO, 1993a) two types of management reference points are described: Target Reference Points (TRPs) and Limit Reference Points (LRPs). The review has been further developed in Caddy and Mahon (1995) and additional references can be found in Rosenberg and Restrepo (1995). A tentative definition of these points is given below.

The MSY Reference Point

The 1982 Convention states that stocks should not be driven below the level of abundance that could produce the Maximum Sustainable Yield (MSY). For decades, MSY has been used, explicitly or implicitly, as a reference point by research, development and management and considered as a bottom-line threshold for stock "sustainability"[27]. Research has amply argued, since the early sixties, that even at MSY, stock instability and risk of recruitment failure are sometimes already high (Christy and Scott, 1965; Larkin, 1977; Gulland, 1969, 1977, 1978; Sissenwine, 1978). This, added to the fact that MSY and the fishing rate corresponding to it are usually difficult to determine accurately, should lead to consider MSY as a non-precautionary target, particularly for stocks with low resilience or high natural variability. At the 1992 FAO Technical Consultation on High Seas Fishing, attention was drawn to the non-precautionary nature of the traditional MSY reference point and to the need for more and different reference points as a basis for more precautionary management strategies (Garcia, 1992). New reference points, not foreseen in the 1982 Convention are, therefore, required if management aims at a low risk of collapse.

Target Reference Points (TRPs)

A Target Reference Point (TRP) corresponds to a state of a fishery and/or a resource which is considered desirable and at which fishery management aims. In most cases, a TRP will be expressed in a level of desirable output from a fishery (e.g., related to catch) and will correspond to an explicit objective of the fishery. As mentioned above, MSY (and F_{MSY}) have been considered as TRPs for decades and the dangers of that strategy have been clearly indicated by the scientific community. F_{MAX}, corresponding to the maximum yield per recruit is an even less precautionary target reference point disregarding the risk of recruitment overfishing. Other TRPs may be used which would aim at conserving higher levels of biomass and at reducing the risk of overfishing. These are, for instance, $F_{2/3\ msy}$ (aiming at an annual catch of 2/3 of the MSY), F_{MBP} (where the stock is maintained at its level of Maximum Biological Production), and $F_{0.1}$ (where marginal yield is 10% of the marginal yield of the virgin stock).

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[26]*Ad hoc* Working Group on Reference Points established by the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks in New York, in March 1994 (cf. Annex 3)

[27]Understood by all States as the highest level of withdrawal from the resource (and fishing intensity) allowed by the 1982 Convention. Understood by some States as the recommended target level of development

When a target reference point is reached during a development process, management action should aim at maintaining the fishery system at its level, e.g., through establishment of total allowable catches and quotas or through effort controls (see below the section on Precautionary Use of RPs).

Limit Reference Points (LRPs)

A limit Reference Point (LRP) indicates a state of a fishery and/or a resource which is not considered desirable. Fishery development should be stopped before reaching it and the risk of inadvertently "crossing" the limit should be very low. Limits are usually expressed in biological terms (e.g., minimum spawning biomass required) but could be expressed in economic terms also (e.g., minimum profitability) even though this does not seem to have been done yet. Biological LRPs have a conservation function and are particularly required in a precautionary approach to set the constraints within which the management strategy must operate (Rosenberg and Restrepo, 1995). These LRPs aim, in particular at conserving an appropriate reproductive potential and at avoiding recruitment overfishing. The most important LRPs developed during the last decade are related to the stock-recruitment relationship (Sissenwine and Shepherd, 1987; Rosenberg and Restrepo, 1995; Garcia, in press). LRPs can also be expressed in terms of mortality or biomass limits (see Caddy and Mahon, 1995; Rosenberg and Restrepo, 1995).

A common way to specify LRPs is to express them as a percentage of the virgin biomass (B_0) below which the stock should not be driven. A typical value often referred to is 20% B_0. ICES has adopted the concept of *Minimum Biological Acceptable Level (MBAL)* defined, for each stock, as the level below which the recruitment has a 50% chance of falling below the critical level beyond which it will decrease as a function of stock size. MBAL could also be the level at which residual spawning biomass has a 50% chance of falling below the established 20% B_0safe limit. In practice, these points are not easy to establish and may have fairly large confidence limits. Garcia (in press) describes a methodology to reflect a precautionary approach to tropical shrimp management, based on these concepts, in data-poor situations.

When a LRP is reached, management action should severely curtail or stop fishery development, as appropriate, and corrective action should be taken. In case overfishing has occurred, stock rehabilitation programmes should consider the LRP that would have been adopted for a healthy resource as a very minimum rebuilding target to be reached before the rebuilding measures are relaxed or the fishery is re-opened. An example is given by the rebuilding strategy adopted for the Southeast Australian stock of orange roughy *(Hoplostethus atlanticus)* following heavy overfishing between the late 1980s and the early 1990s. The Australian Fisheries Management Authority has endorsed, starting in 1995, a strategy to base Total Allowable Catches (TACs) with a view to ensure a 50% probability that the stock is at or above 30% of the spawning biomass present at the beginning of the fishery (Phillips and Rayns, 1995). This latter figure will be used, first, as a rebuilding target and, as soon as it is reached (in 2004 according to forecasts), as an LRP.

Precautionary Use of RPs and Threshold Reference Points (ThRPs)

Two major sources of bad performance in a reference points system will be examined below: (a) the accuracy and precision with which the RPs are determined, and (b) their adequation to the fishery system dynamics.

First, because of the uncertainty inherent in their determination, reference points should preferably relate to probabilities[28] (e.g., specifying both their central value and confidence limits). This uncertainty as well as the uncertainty in the current value of the fishing mortality or stock biomass, imply a certain probability that these RPs be "missed". For example, management regimes using MSY or FMSY as TRP will meet the objective only **on average**, with 50% chances of a slight "overfishing" or "underfishing", in case of a normal distribution of probabilities. Assuming full control of the fishery, the seriousness of the "statistical" vagaries around the objective will depend on the breadth of confidence limits of the TRP estimate and the potential consequences of a exceeding the target with a certain frequency and to a certain extent. If these consequences appear unacceptable, a more precautionary approach will be needed.

Second, the fishery system has its own dynamics and fishing fleets have a high level of inertia (resistance to change), due to various financial, technical, cultural and administrative reasons. As a consequence, stopping their evolution and expansion and reversing or only modifying historical trends are not trivial tasks and may require time in addition to political will and incentives. Similarly, the life parameters of long-lived target species (e.g., low natural mortality and fecundity, late maturation and slow growth) are such that reversing resource trends and promoting their recovery once depleted may require some luck (on the environmental side) and some time. There is therefore a risk that, having reached a TRP or approached a LRP, in the course of a dynamic development process, it takes too long to effectively stop the fishery's evolution in this desirable situation, overshooting the target and, possibly, crossing the limit. As a consequence, more precautionary reference points and decision rules might be required in order to avoid or reduce the need for costly corrective action and to limit the amplitude of the oscillations of the fishery around its target and limits.

Two solutions are generally offered to deal with both of these problems: (a) choosing more precautionary references, and (b) using the references in a more precautionary way.

Firstly, it is possible to select different reference points based on the level of precaution desired, or risk considered as acceptable, as shown in the two preceding sections, and this is usually achieved at the expense of foregoing some potential economic benefits. It is self-evident that selecting $F_{0.1}$ or

$F_{2/3\ MSY}$ as TRPs instead of F_{MSY}, for instance, is sufficient to reduce the risk of overfishing. Similarly, choosing 20% of the virgin stock spawning biomass as a LRP is less precautionary than putting this limit at 30%[29]. In addition, some reference points can be used either as TRP or LRP depending on the level of precaution to be ensured. In principle, trying to avoid reaching a reference point (i.e., using as a limit) instead of trying to meet it on average (e.g., using it as a target) should reduce the probability to go beyond it. It is for this reason that F_{msy}, which has been considered as a target for decades, is now proposed as a LRP, as a **minimum international standard**, or as a minimum target for stock rebuilding strategies (cf. Annex 5, paragraphs 1 and 16), illustrating the shift of contemporary scientific advice towards more precautionary strategies. One could select $F_{2/3MSY}$ as a TRP because of its *a priori* better performance in terms of risk to overfish and this strategy could be as precautionary as using F_{MSY} as a LRP. In practice, the two references could be indeed used together, e.g., $F_{2/3MSY}$ as a target and B_{MSY} as a limit.

[28]For example, a "**Minimum Biological Acceptable Limit**" (MBAL), related to recruitment or reproductive biomass would be defined as a level beyond which the recruitment has a 50% chance to fall below a critical level (R_{max} for instance or R_{mean}) or the residual spawning biomass (escapement) has a 50% chance to fall below 20% of the virgin stock spawning biomass

[29]An example of such conservative setting of biological limits is given by the Revised Management Procedure of the International Whaling Commission (IWC) which sets the lower stock limit at 54% of the carrying capacity, a level sometimes considered as excessively conservative (Kirkwood and Smith, 1995)

Secondly, it is possible to keep the same RPs, using them differently. The probability to inadvertently "cross" a TRP when aiming strictly at it, is 50%. A different and more precautionary probability could, however, be in-built in the related decision-rule, e.g. by deciding that annual fishing mortality should not be allowed to exceed the TRP value more than 10% of the time instead of 50% of the time, or by leaving the LRP value at 20% of the virgin stock but agreeing that the acceptable probability to exceed the limit should be 25% and not 50%. These results could indeed only be obtained by fishing at a level somewhat lower than otherwise possible, on average, and this second solution is therefore equivalent to replacing the reference point by a more precautionary one (see Figure 2). Similarly, Caddy and Mahon (1995) stress that the lower the precision of the mortality estimates (e.g., their coefficient of variation), the lower the "safe" target fishing level for a given level of risk.

Precaution will be ensured by combining TRPs and LRPs which will most often refer to different control or status variables of the fishery system. For instance, a TRP might be established in terms of a proportion of MSY (e.g., two thirds of MSY) and used simultaneously to LRP established in terms of spawning biomass (e.g., 20% of the virgin spawning biomass). The implication is that the manager will develop the fishery towards producing two-thirds of MSY while monitoring carefully the decreasing spawning biomass as effort increases (just as a captain would aim the vessel towards a destination while watching the depth under the vessel's keel). The manager will immediately change the fishery TRP, or the way the TRP is being approached, if the LRP is being too rapidly approached or is dangerously close (e.g., just as the captain would modify the destination or the route with its equipment to indicate a reef ahead or a rapidly decreasing depth). A non trivial consequences of this approach is that the TRPs and LRPs should be compatible (e.g., the fishing mortality at which the TRP catch is obtained should obviously be significantly lower than that at which the LRP spawning biomass could be "crossed").

Another solution suggested in Garcia (1994a) is to use **Threshold Reference Points (ThRPs).** A ThRP indicates that the state of a fishery and/or a resource is approaching a TRP or a LRP and that a certain type of action (preferably agreed beforehand) is to be taken to avoid (or reduce the probability) that the TRP or LRP is accidentally exceeded. It provides an early warning when critical reference points are being approached, reducing the risk that these points (and the management objectives they materialize) be violated. Just as in high inertia computerized tankers, alarms are pre-set to be automatically triggered if the distance to other vessels or the depth under the keel falls below a pre-determined safety value. This could be done, if the cost of permanently reducing the fishing mortality (and fisheries output), as suggested above, was not considered justified in regard to the risk. Adding precaution to the management set-up but also burden, ThRPs might be necessary only for resources or situations involving the particularly high risk related to the nature of the target stocks or the type of fishery development process.

It is paradoxical, however, that ThRPs might not be usable when they would be most needed, i.e., when natural variability is high or data is scarce. Under these conditions, the confidence limits of the estimates of the current level of exploitation (e.g., in terms of fishing mortality, $F_{current}$), the TRP (e.g., the target level of fishing mortality, F_{TRP}) and the LRP (e.g., the higher limit allowed for this mortality, F_{LRP}), might be too large to allow statistically significant discrimination between them. The precision with which the estimates can be made determine therefore the **resolution of the reference points system**, and the number of points that can realistically be used simultaneously (see Figure 3).

The medium-term oscillations of the resources potential and properties (e.g., on circa-decadal scales) can be a significant cause of loss of performance of management systems and of serious crashes of the resource base. Famous examples are given by the collapse of the Peruvian anchoveta stock under El Niño, in the early seventies and, possibly, the collapse of the Atlanto-Scandian herring and Canadian Cod stocks in the North Atlantic. It is difficult to give a generic prescription relating RPs to these events. Cooke (1994), stressed that in order to be useful for management, reference points should retain their validity in the face of short- and long-term fluctuations in fish stocks due to recruitment variability and other factors. For events already observed in the past, the probabilities of their occurrence should be taken into account, including through their forecasting and related adjustment of the TRP. If such probabilities are not available a fully rational approach is probably not possible but some contingency plans or other safety-net arrangements might be instituted.

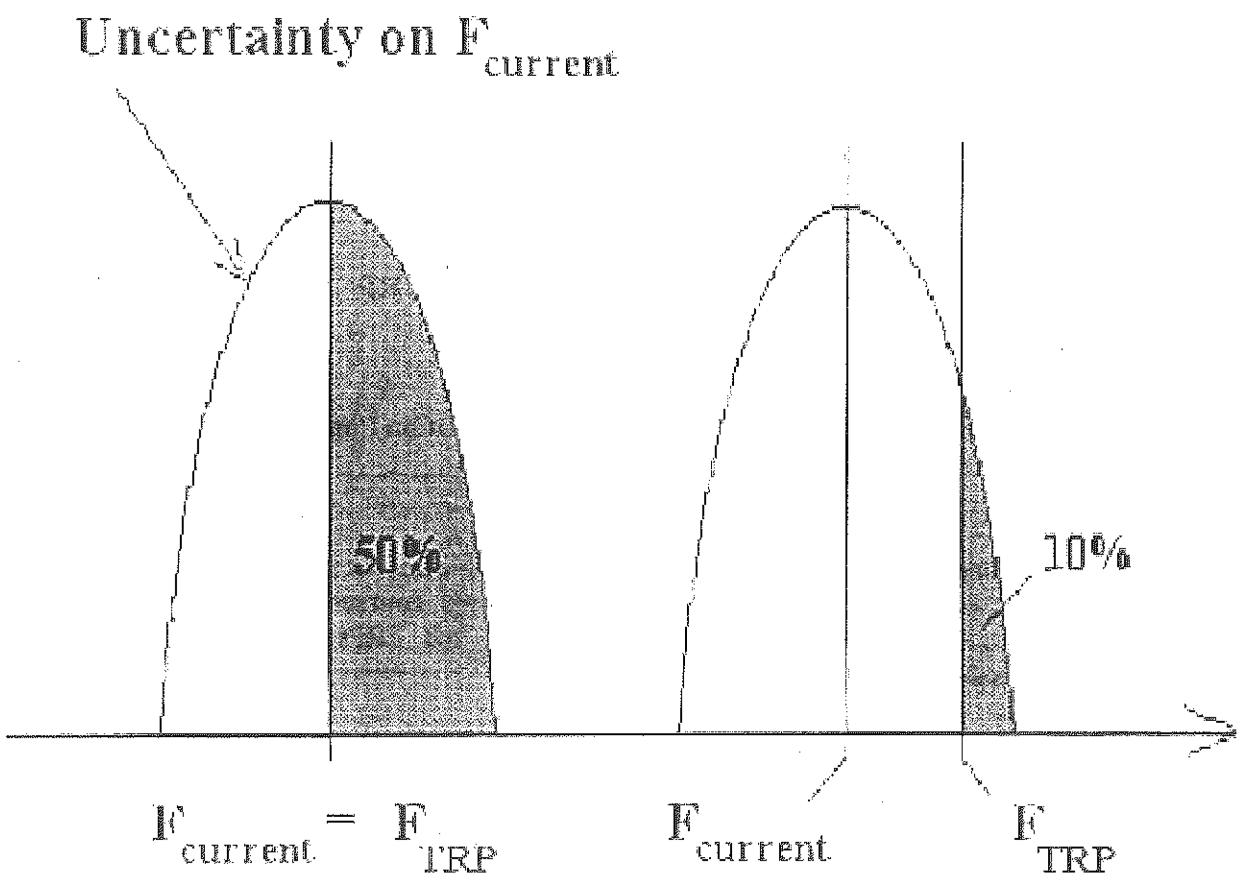

Figure 2: Relation between the effectively achieved level of mortality ($F_{current}$) and TRP

level (F_{TRP}) when a 50% or 10% probability to inadvertently exceed the TRP is accepted.

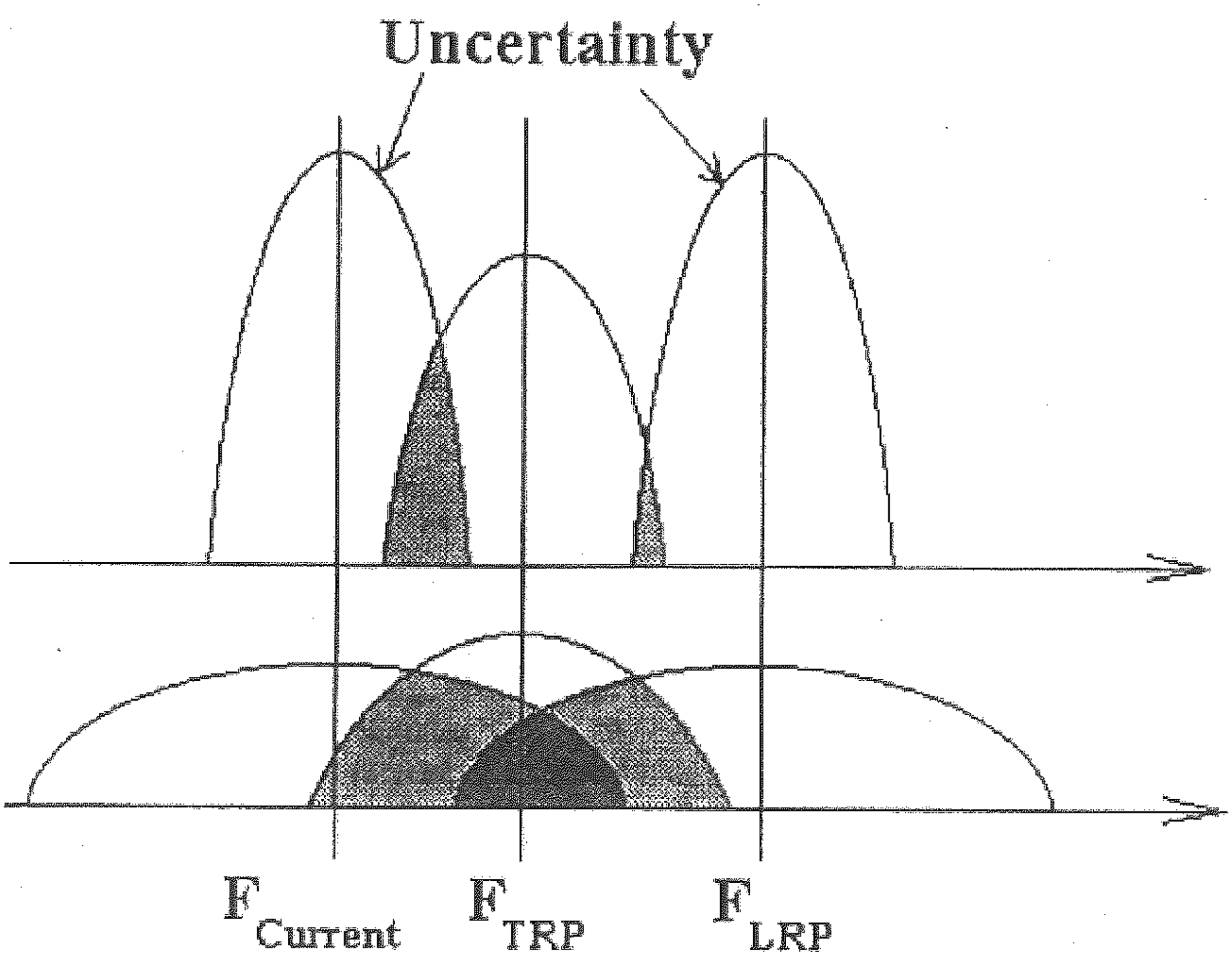

Figure 3: Illustration of a low variability/high resolution (top) and a high variability/low resolution reference points system.

As mentioned earlier on, preventive action is preferable but not always possible, and effective reactive capacity is important. In this respect, **pre-agreed courses of action**, "automatically" triggered when TRPs are reached, ThRPs are crossed, and LRPs are approached, would be particularly advisable, in particular:

- when the probability of occurrence of an unwanted negative outcome is particularly high (e.g., in areas of high environmental variability such as upwellings or semi-arid climates;
- for species which are at the extreme end of their geographical range of distribution or with particularly low resilience (e.g., small cetaceans, sharks, etc.), and
- when the potential cost of inadvertently "breaking the rules" could be particularly high.

Management strategies and control laws

The management strategy which establishes the way by which it is planned to reach stated objectives is largely determined by these objectives (which also determine the selection of TRPs), the conservation constraints imposed on the fishery (as materialized by the selected LRPs), and the pre-agreed course of action to be taken depending on the position of the fishery in relation to the RPs system. The management strategy will state, *a priori*, the acceptable probability that the LRP is violated (while apparently it is not!). The related decision-rules will be case-specific, depending on the characteristics of the stock (its resilience) and the type and flexibility of the fishery. A management strategy or control law can be graphically represented and summarized as in Figure 4. Its performance in terms of satisfying the objective (meeting the TRPs) and the conservation constraints (meeting the LRPs), can be tested by simulation (Restrepo and Rosenberg, 1994).

Socio-economic reference points

Some economic TRPs are available in theory but have been rarely applied in practice, such as MEY or F_{MEY} (the level of effort corresponding to Maximum Economic Yield) at which the fishery generates its highest rent. This reference point is usually located well below F_{MSY} and has, therefore, better conservation properties. On the contrary, the Maximum Employment criteria (a level never defined in theory but one of the most used, at least implicitly, by "laisser faire" management strategies) implies developing fisheries well beyond F_{MSY}, generating high risk for the resource.

The concept of socio-economic LRP does not seem to have been used or even formally proposed but they could be developed as management systems will make more explicit use of economic theory. For instance, in order to avoid having to subsidize a national fishery, a reference point could be determined, at an effort level (fleet size) where the revenue would be equal to **all** costs, including the cost of research, control, surveillance and enforcement, indicating the maximum acceptable fleet size or effort level.

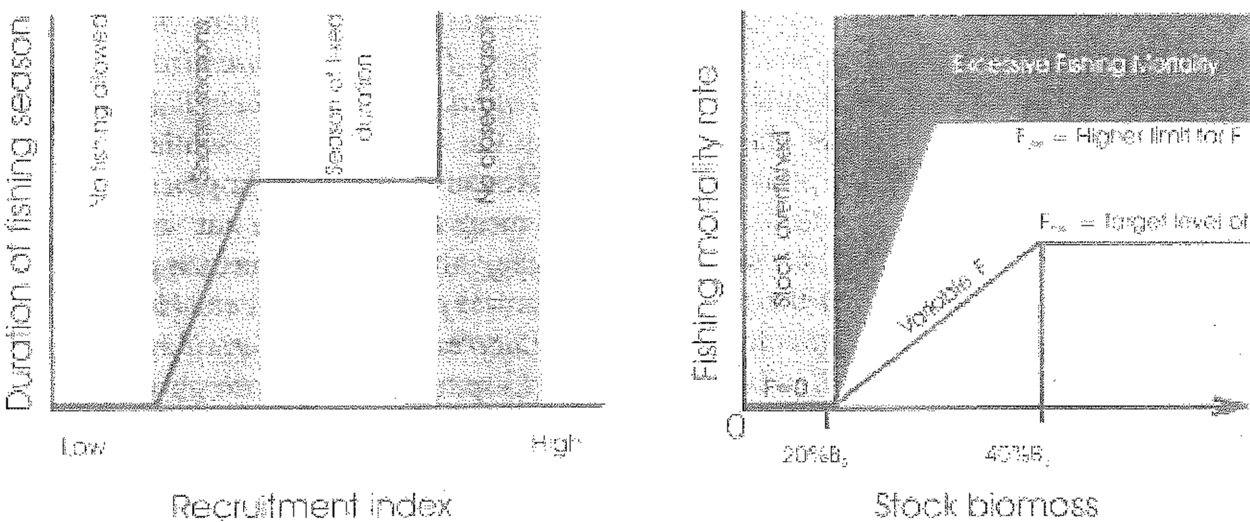

Figure 4: Representations of management strategies. Left: Regulation of the duration of the fishing season as a function of annual recruitment (from Garcia, 1996). Right: regulation of fishing mortality as a function of the stock biomass (modified from Rosenberg and Restrepo, 1995).

A major difficulty in selecting socio-economic reference points for management, including reduction of overcapacity, resides in the task of determining the appropriate position (level of effort, or fleet capacity) corresponding to the mix of socio-economic objectives, often ill-defined, assigned to a fishery. The little success met by the concept of Optimum Yield (OY) illustrates this problem. The difficulty in confronting the socio-economic complexities of a precautionary approach to fisheries was reflected in the difficulties met by the Technical Consultation on the Precautionary Approach to Capture Fisheries (FAO, 1995) to deal properly with artisanal fisheries for which a particular reflexion is still required.

Another difficulty is in cost-benefit analysis. It should be evident that the cost of the measure should be matched by its future benefits but that calculation is not trivial and is complicated by the multiplicity of stakeholders, the diversity of their objectives and time preferences, the different implications of the so-called "future discounting" for different groups[30], and the likelihood that they will effectively receive the theoretical benefits (Shotton, 1994).

To circumvent, at least partially, these difficult, pragmatic decision rules could also be established on economic grounds, related, for instance, to fishing capacity: e.g., if capacity increases faster than catches for a given number of years, then some capacity freezing action is taken. If capacity is higher than that required to take the allowable catch by more than a given percentage, then it should be reduced, etc. The selection of socio-economic decision rules and economic reference points is difficult enough in national fisheries. In management of high seas, straddling and highly migratory stocks, the difficulty is even higher owing to the divergence of economic situations of the various national stakeholders. In such a situation, the selected rules and references would have to be general enough to be acceptable to all parties and specific enough to be of practical use.

Ecosystem reference points

Ecosystem management is being recognized with increasing frequency as the necessary basis for fisheries management and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is often cited as the champion of the ecosystem management concept. The CCAMLR convention refers to "*the maintenance of ecological relationships between harvested, dependent and related species*" as well as the "*prevention of change or minimization of the risk of change in the marine ecosystem which are not potentially reversible*". This requirement is precautionary in nature in the sense that it requires that the integrity and essential functions of the ecosystem must be preserved as a prerequisite to fisheries sustainability. In practice, however, we do not yet know how to manage entire ecosystems. In most cases we have not yet even understood completely how they function, why and how they fluctuate, what are the structuring variables and we cannot predict the future states of the ecosystem we are exploiting. Walters (1986) stresses that "*ecosystems are moving targets, with multiple potential futures that are uncertain and unpredictable. Therefore management has to be flexible, adaptive and experimental at scales compatible with the scales of critical ecosystem functions*". The recognition of this uncertainty has sometimes led, in the international debate on the precautionary approach, to replace the requirement for ecosystem management (implying control on all elements of the ecosystem) by the more specific and practical goal of conserving not only the target species but also the associated and dependant species. If the balance between ecosystem components must be maintained, minimizing by-catch or using extremely selective gear, as common sense suggests, might not be the best solution. It has been proposed, for instance, that in multi-species management, a reasonable strategy would be to exploit all species in proportion to their abundance in order to maintain the overall ecosystem structure (Garrod, 1973). This is, however, not easy to achieve without wastage of less demanded species and additional work is certainly required on this matter before objective guidance can be given.

[30] Considering the major impact of discount rates, the uncertainty about their future evolution, and the likely difference between "local" and "global" rates, a key problem of establishing socio-economic reference points is that of agreeing on these rates

More research is needed to develop specific guidelines and reference points for a precautionary approach to aquatic ecosystems exploitation, related for instance to global stress indicators, resilience factors, critical habitat conditions, acceptable impacts etc. Clarification is also required on the meaning of **ecosystem sustainability** and on the issue **"impact reversibility"**. Ecosystems have a degree of natural variability and can shift from one equilibrium state to another because of natural environmental variability or human stress and under these conditions sustainability cannot mean constancy. As far as reversibility is concerned, fisheries management may be able to suppress unwanted fisheries impacts (e.g., through fleet reduction schemes, protected areas, etc.) and rebuild productivity but there is no assurance that the ecosystem could be returned exactly to its **pristine state**.

Some of the aims and principles of ecosystem management can be found in the management charter of CCAMLR and in the 1990 Strategy for Sustainability elaborated by IUCN. These include: minimizing conversion of critical ecosystems to "lower" conditions, compensating habitat conversion with restoration (allowing no net loss)[31], maintaining ecological relationships, maintaining populations at greatest net annual increment, restoring depleted populations, minimizing risk of irreversible change in the marine ecosystem, etc. Holling (1994) maintains that ecosystems are structured by a small number of biotic and abiotic processes which organize its behaviour and that when investing in the protection of ecosystems (biodiversity), priority should be placed on maintaining these structuring variables. A useful principle could be to aim at maintaining all the fundamental components of the ecosystem (nurseries, spawning areas, feeding areas, migration routes, etc.) in order to ensure permanency of the ecosystem structure even though the abundance (or even the permanence) of some of its species components cannot be absolutely warranted. Genetic conservation guidelines, when introduced, will make matters even more complicated as management will have to meet conservation requirements at the ecosystem, biodiversity, species and genetic levels (cf. ICES. 1995).

7.4 Practical Guidelines

In most fishery systems, a progressive but systematic and decisive shift towards more risk-averse exploitation and management regimes is advisable. This implies that precautionary measures for fisheries management should be widely used as a means to avoid crises and reduce long-term costs to society. Because uncertainty is pervasive in the ocean ecosystem and fisheries, precaution should become an integral part of fishery management systems, to be applied routinely in decision making. Unnecessarily stringent and costly measures, should be avoided as they would rapidly become counter-productive by deterring fishery authorities from using the concept as widely as possible and discrediting the approach among industry.

A precautionary management strategy would need both a sufficient **preventive capacity** to avoid predictable problems, and enough **reactive (corrective) capacity**, flexibility and adaptability to ensure a safe "trial-and-error" process, as knowledge about how the system works is collected. It should recognize the uncertainties in the data and promote adaptability and flexibility of management regimes through appropriate institutions and decision-making processes. It would rely not only on expert advice but also on people's participation. As stated by Holling (1994) *"effective investments in a sustainable biosphere are therefore ones that simultaneously retain and encourage the adaptive capabilities of people, of business enterprises and of nature"*. In case of doubt, decisions should **"err on the safe side"** with due regard to the risk for the resource and the social and economic consequences.

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[31] This concept of "compensation", which proposes that human activities should lead to "no net loss of habitat", implies that, if some part of a habitat must be damaged somewhere, compensation is provided somewhere else

A fishery management policy based on a reasonable interpretation of the concept of precaution should: (a) explicitly adopt the principle of sustainable development as defined by the FAO Conference (given in the introduction to this paper); (b) explicitly state a set of objectives that are compatible with this principle, and (c) adopt a precautionary approach based on the following measures:

Promotion and use of research

1. Promote research in support of the precautionary approach to management, e.g., research aimed at understanding better the conservation requirements of the ecosystem, biodiversity, species and genetic levels as well as research towards a better definition of management reference points, including economic ones.

2. Use the best scientific evidence available and, if it is not sufficient, invest in emergency research while interim management measures are taken at the level required to limit risk of irreversible damage.

3. Improve information systems commensurate with the level of risk, covering costs through fishing fees as required, addressing all resources, directly or indirectly affected and promoting joint research programmes in international and regional arrangements.

4. Experiment with management strategies and pilot development projects with the support of

research, generalizing the use of Environmental Impact Assessment (EIA).

Reference points, rules and criteria

5. Adopt a set of objectives for the fishery and a related set of reference points (broader than the traditional MSY) and management benchmarks, and use the latter to measure the efficiency of the management system (e.g., in terms of achieving production targets, controlling fleet capacity, and maintaining spawning stock size or recruitment levels).

6. When alternative options are considered, adopt a risk-averse attitude, considering *a priori* that: (a) fisheries are likely to have a negative impact on the resource, and (b) risk of unacceptable or irreversible impact should be minimized.

7. Ensure that precautionary management plans specify, *inter alia*, the data to be collected and used for management and their precision, the methods of stock assessment, the decision rules and reference points needed for determining and initiating management measures as well as contingency measures to be taken in case of danger for the resource.

8. Adopt provisional reference points when data are poor or lacking, establishing them by analogy with other similar and better known fisheries and updating/revising them as additional information becomes available.

9. View Maximum Sustainable Yield (MSY) as a minimum international standard, ensuring that fishing mortality does not exceed the level needed to produce it and that stock biomass is maintained above it (or rebuilt at least at this level).

10. Adopt precautionary management reference points defined on the basis of agreed scientific procedure and models, including Target Reference Points (TRPs) and Limit Reference Points (LRPs). Because of the uncertainty inherent in their determination, these reference points should preferably be expressed in statistical terms (i.e., with a central value and a confidence interval).

11. Adopt action-triggering thresholds and management strategies which include pre-agreed courses of action, automatically implemented if the stock or the environment approaches or enters a critical state as defined by pre-agreed rules, criteria and reference points[32].

12. Adopt Threshold Reference Points (ThRP) where specific conditions require added precaution, to indicate that the state of a fishery and/or a resource is approaching a TRP or a LRP and that a certain type of action (preferably agreed beforehand) is to be taken, to avoid (or reduce the probability) to accidentally go beyond the selected TRPs or LRPs.

13. Ensure that management action maintains the stock around the selected TRP on average (e.g., through establishment of total allowable catches and quotas or through effort controls) and that the probability of exceeding the target, and the extent by which it is exceeded, are kept at acceptable levels.

14. Severely curtail or stop fishery development, as appropriate, when the probability of exceeding the adopted LRP is higher than a pre-agreed level and take any corrective action deemed necessary. If the LRP is indeed exceeded, implement a stock rehabilitation programme using the LRP as a minimum rebuilding target to be reached before the rebuilding measures are relaxed or the fishery is re-opened.

15. Bring into force, “automatically” the set of pre-established measures, or courses of action, when a ThRP is reached particularly in cases or situations involving high risk.

16. Ensure that selected reference points are robust to short- and long-term fluctuations in fish stocks due to recruitment variability and other factors and that they are periodically re-assessed as new data is collected and new understanding or methods become available.

17. For newly discovered stocks, establish safe biological limits (in absolute or relative terms[33]) and threshold reference points from the onset; prohibit large scale development; limit removals, through effort and catch limitations and resource allocation schemes, to a fraction of the stock well below annual natural mortality; set-up monitoring and assessment programmes on the target and associated species.

18. Aim at maintaining the fundamental components of the ecosystem (nurseries, spawning areas, feeding areas, migration routes, etc.), minimizing their degradation and, where possible, re-establishing them in order to ensure permanency of the ecosystem structure and productivity mechanisms even though the abundance (or even the permanence) of some of its species components cannot be absolutely warranted.

[32]One of these courses of action could be a moratorium. However, if reference points are selected on a cautious basis, and monitoring produces information on a quasi-real-time basis, a range of more cost-effective alternatives should be available (seasonal or temporary closures, modification of fishing patterns, significant reduction of effort, etc.)

[33]That is, as a proportion of the virgin stock

Acceptable impacts

19. Promote discussion and agreement on acceptable levels of impact (and risk) in a process that will identify trade-offs and promote transparency, particularly in relation to public opinion.

20. Take into account the combined stresses of fishing and environment on resources. Effort reductions may be imposed or special measures affecting fisheries taken when the stock faces unusually unfavourable environmental conditions.

21. Address as far as possible all combined stresses to the resource, including those imposed by non-fishing activities or related to natural fluctuations[34].

22. Prohibit irreversible impacts as well as decrease of any population of marine species below the which ensures the greatest net annual increment of biomass (i.e., the MSY level). For overfished fisheries, an important objective should be to rebuild the stock at least to that level.

23. Set catch and effort levels for target species in accordance with the requirement that they do not result in unsustainable levels of mortality for both target and non-target species.

Management framework

24. Manage fisheries in the context of integrated management of coastal areas, raising sectoral awareness about exogenous impacts on the state of the resources and on fisheries productivity.

25. Improve public awareness, as well as consultation of non-fishery users, taking all interests into account when developing and managing fisheries, as required in Agenda 21, improving management transparency and reporting procedures.

26. Improve decision-making procedures, replacing consensus decision-making by voting procedures wherever possible.

27. Strengthen monitoring, control and surveillance, thereby improving detection and enforcement capacity (including legal tools), raising penalties to deterrent levels, and exerting more effectively the responsibilities pertaining to the flag or the port States.

28. Avoid overburdening of management systems and industry by limiting the number of precautionary devices and measures implemented at all times, based on an analysis of the probability of occurrence of negative impacts of a certain magnitude, pre-agreed as part of the

management scheme and reflected in appropriate reference points.

29. Establish safety-net arrangements (e.g., in terms of insurance, compensation, etc.) to protect the users from the consequences of exceptional hazardous occurrences.

30. Establish precautionary management regimes for all resources, across their whole area of distribution, whether in EEZs, in the high seas, or both (high seas, straddling and highly migratory resources).

[34]This means that restrictive action on fishing might be needed even when the causal mechanism is natural (e.g., related to El Niño, droughts, or other medium-term natural fluctuations)

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More details

THE PRECAUTIONARY APPROACH TO FISHERIES AND ITS IMPLICATIONS FOR FISHERY RESEARCH, TECHNOLOGY AND MANAGEMENT: AND UPDATED REVIEW (Continued)

CONCLUSIONS

The present status of many fishery resources around the world indicates that management practices need to be improved. An acceleration of the process of evolution of fisheries management and a broadening of its scope are required to take fully into account the explicit requirements of the 1982 United Nations Convention on the Law of the Sea, UNCED Agenda 21, the Convention on Biological Diversity, the outcome of the International Conference on Responsible Fishing (Mexico, 6–8 May 1992), the outcome of the UN Conference on Straddling Fish Stocks and Highly Migratory Fish stocks (New York, 1993–95), and the FAO International Code of Conduct for Responsible Fisheries. The uncertainty and risk resulting from the limitations in fisheries management systems and scientific information, as well as natural variability (including climate change) is progressively being recognized and should be taken into account by adopting more precautionary management strategies.

The need for precaution in management has been reflected in the precautionary principle and the precautionary approach, two concepts sometimes difficult to distinguish perfectly. The precautionary principle has suffered from lack of definition, extreme interpretations leading to moratoria and lack of consideration of the economic and social costs of its application. The precautionary approach has been more closely associated with the concept of sustainable development and sustainable use, recognizing that the diversity of ecological and socio-economic situations each may require different strategies. This concept has, therefore, a more acceptable "image" in the various development and management sectors and is considered more readily applicable to fisheries management.

An objective analysis of the sources and nature of the uncertainty, its potential consequences in terms of an error, its cost, and its potential reversibility, leads to the conclusion that the sustainable development of fisheries requires indeed a combination of approaches (i.e., corrective, preventive, or precautionary) and may even, in extreme cases, resort to the precautionary principle. Considering the range of uncertainty that affects various areas of fisheries and the magnitude of potential costs of errors that might be made, it is possible to represent the respective domains of application of these approaches on an uncertainty/cost diagram (Figure 5). While it is recognized that the position of the current fishery issues on such diagram may be sometimes a matter of debate and will vary from case to case, some of these issues, and the instruments available to address, them have been tentatively represented in Figures 6 and 7 respectively with a view to illustrate the proposed typology of approaches.

1. **The preventive approach** intends to actively prevent (avoid the occurrence of) unwanted consequences of human action. It is justified and safely usable, irrespective of the cost of potential errors, when the uncertainty is so low (and the scientific and other understanding so comprehensive) that measures can be designed with a very large probability of success (e.g., of achieving what was intended) avoiding major drawbacks and, in conditions of full or very

high reversibility, any negative impact. This approach relies on engineering research and deterministic science and is usually appropriate for micro-issues (e.g., improving gear selectivity, reducing environmental damage from land-based fish processing, engine exhausts fumes, or refrigerating equipment and improving compliance, etc.).

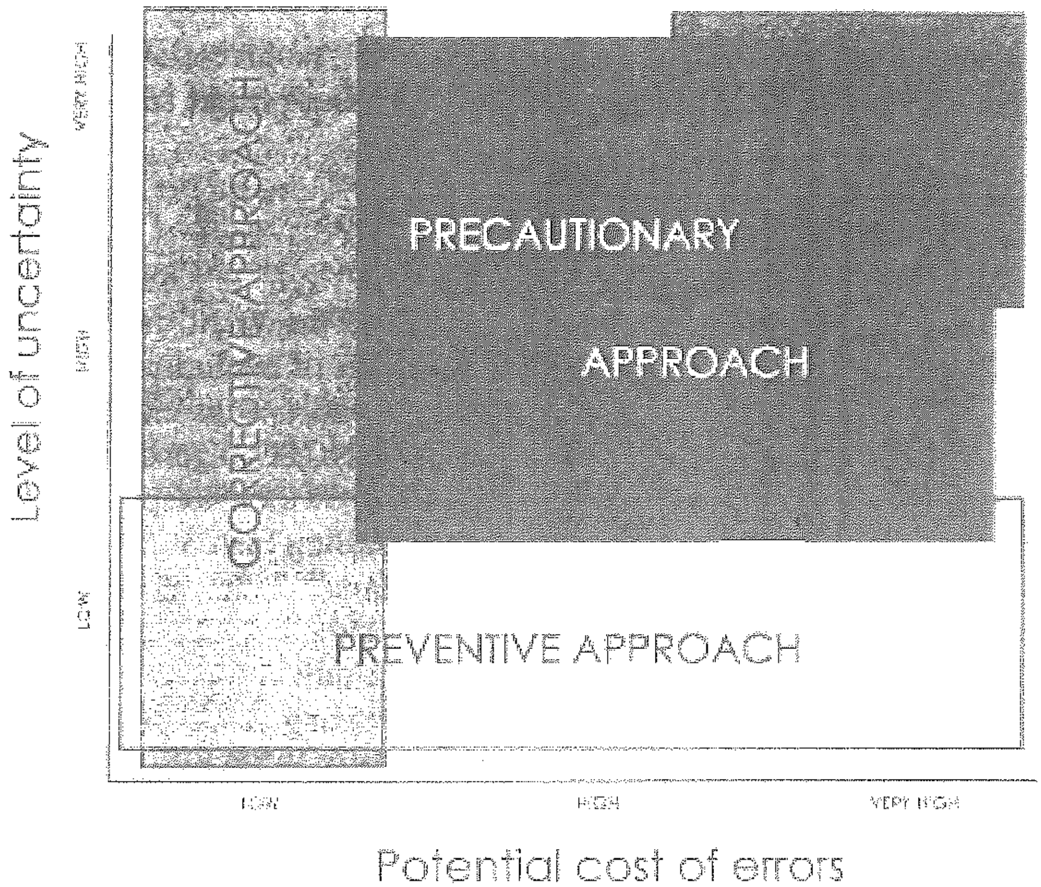

Figure 5. Domains of application of the various possible approaches to fisheries development and management in relation to the level of uncertainty and potential cost of errors.

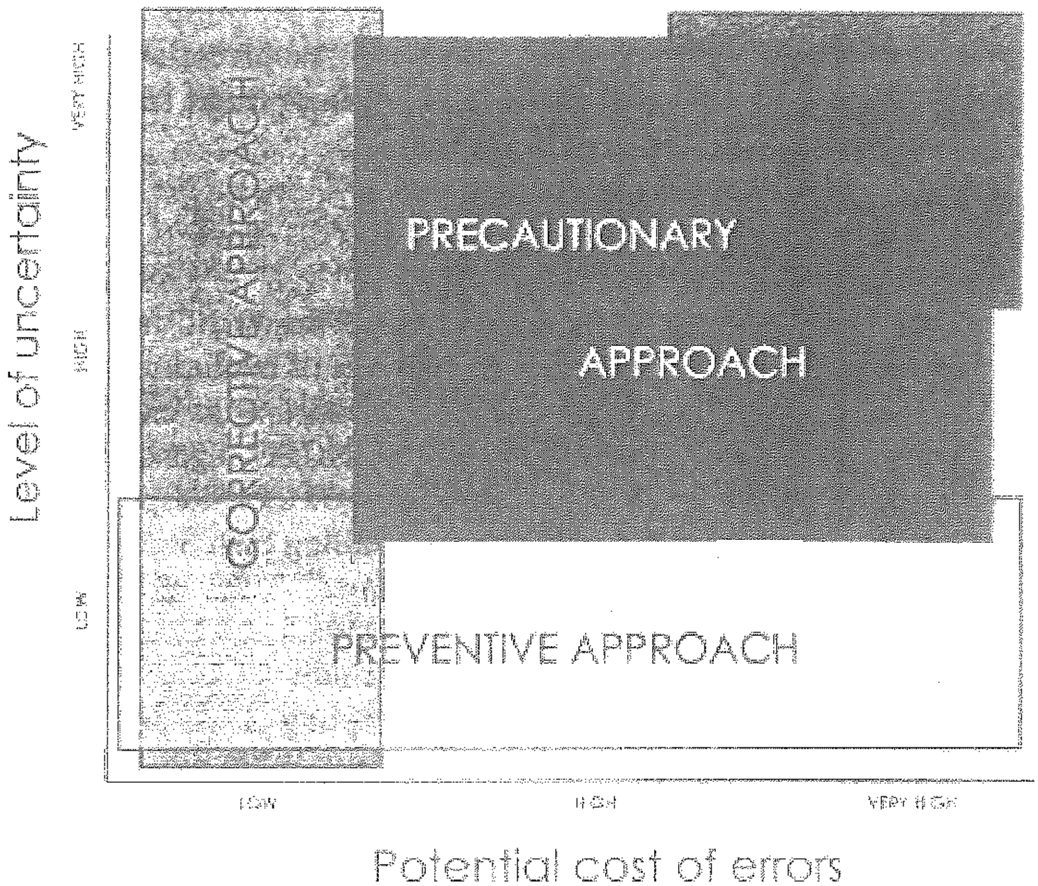

Figure 6. Positioning of current fisheries issues in relation to potential approaches on the uncertainty-cost diagram.

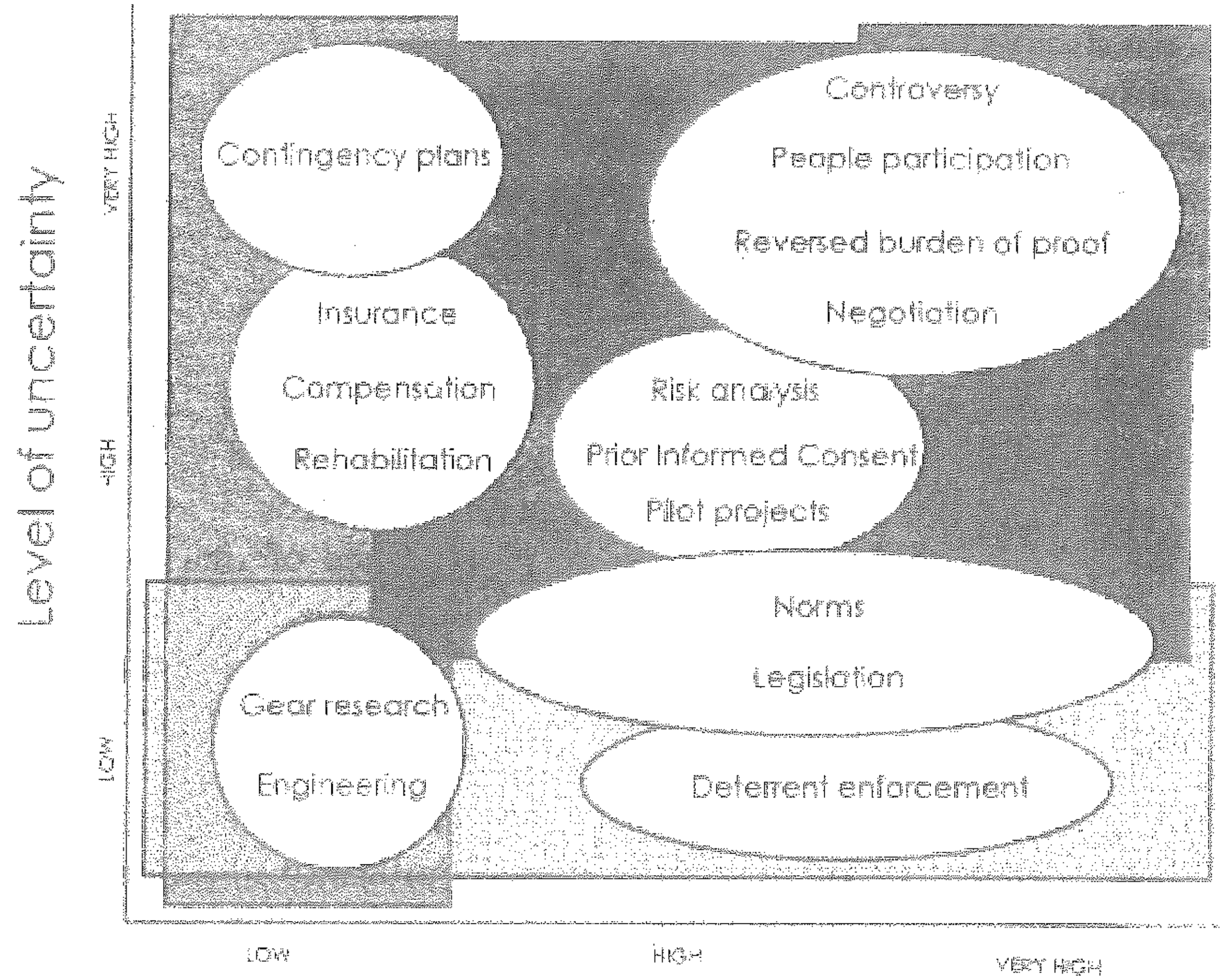

Figure 7. Positioning of currently used fishery regulations in relation to potential approaches on the uncertainty-cost diagram.

2. **The corrective approach** is empirical and intends to correct effectively the consequences of actions, the potential consequences of which were not considered *a priori* or disregarded as negligible. This approach is justified, irrespective of the level of uncertainty, when the cost of the potential errors are negligible, or low, and in any case much lower than the cost of avoiding the errors (cost-benefit analysis), and when the consequences are perfectly reversible or totally acceptable (even though not reversible). The approach consists in taking the best measures possible (the easiest to implement), not assuming perfect knowledge, but assuming that progress will be ensured through "trial and error"[35] with no long-term risk for the resource. It would be also relevant for micro-issues (e.g., to improve vessel safety, gear selectivity, closed seasons, etc.).

3. **The precautionary approach** aims at reducing the probability of occurrence of bad events within acceptable limits and is used when the level of uncertainty and the potential costs are significant, when full reversibility may not be ensured (but AT LEAST partial reversibility[36] is highly likely). It requires, *inter alia*, the maintenance of a flexible, resilient fishery system (including the fish stock, the associated species, the fleet and the management agency regulating it). It addresses meso-issues which are central to the management of the fishery system such as resources sustainability and recruitment overfishing, protection of non-target and endangered species, environmental management of aquaculture, development of new fisheries and maintenance of ecosystem productivity.

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[35] Adaptive learning is recommended under the precautionary approach but it has applications across the entire

uncertainty/cost diagram

[36]Partial reversibility is achieved when the system can be returned to a state (in terms of health or productivity) equivalent, but not identical, to the pristine state

4. **The precautionary principle** aims at avoiding irreversible damage and high costs to the resources (and society) in cases of high uncertainty (edging on ignorance). It corresponds to situations where scientific theories are not yet formed, or controversial and where the scientific process tends to lead to conflictual polarization instead of consensus. Under these circumstances, the scientific debate tends to be replaced by political lobbying and negotiation, often with a large contribution by the media and NGOs. This instrument would be used, in most cases, to deal with on macro- and mega-issues and where reversibility (even partial reversibility) is highly unlikely. There are few issues of this nature in fisheries, e.g., perhaps species introductions (whether voluntary and accidental). Some problems affecting fisheries directly, however, could require the application of the principle, e.g., the destruction of critical habitats by other sectors, the ozone depletion, and the global warming.

Close to the origin of the graph (on Figure 5), where both uncertainty and potential costs are low, the corrective and preventive approaches overlap significantly in a "neutral area" where both approaches could be justified. As a matter of fact, Figure 5 shows that the area of application of the four strategies overlap and the meaning of the often used expression "erring on the safe side" or "giving to the resource the benefit of doubt", in this particular context, is that issues falling between two or more approaches should be addressed using the more precautionary approach.

The existing set of principles and guidelines agreed at international level, in the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, and in the FAO Code of Conduct for Responsible Fisheries relate in fact to the first three approaches indicated above. It appears therefore that the operational understanding of a "precautionary approach" *lato sensu* to fisheries in the inter-governmental quarters (and also of many NGOs) includes all the methodologies, instruments and devices which ensure that the consequences of human action on the resource and its environment are acceptable because either: (a) we know what to do to avoid the problems; (b) or the cost will be negligible and the error can be corrected, or else (c) we are conscious of limitations in data and act accordingly. The present state of fisheries indicate clearly that up to now, Governments have used corrective or "preventive" strategies in cases where more precaution was required.

The problem lies in using the proper approach for each type of issue. On the one hand, over-protecting the resource (by taking a highly precautionary approach) may have significant consequences in terms of foregone development options and could lead to economic and social chaos in fishing and related industries and communities and the fishery sector which rightly refuses to be assimilated to a polluting industry. On the other hand, being over-optimistic as to human capacity to regulate sustainably the production system for its benefit while preserving the options of future generations, could also have significant negative consequences for the resources and, ultimately, for fishing communities.

The real challenge in the implementation of the precautionary approach to fisheries, assuming that Governments' political will and commitment is granted, is therefore to distinguish in which area of the conceptual uncertainty/cost diagram an issue falls when a decision is required. This is an area where fishery science can help and towards which fishery research agendas should be directed. Section 5 of this paper and the "Lysekil Guidelines" (FAO, 1995) provide useful indications for that purpose but a lot more work is required to allow all countries, at all levels of research capacity, to apply the approach effectively.

The principle of precautionary action, as traditionally stated, required fisheries management authorities to take action where there is a risk of severe and irreversible damage to the resources and the environment, even in the absence of certainty about the impact or the causal relationships, giving the resource the benefit of the doubt, with due consideration to the social and economic consequences. The broader precautionary approach described in this document, and transpiring from the agreements being developed in the international fishery arenas (particularly in the UN and FAO), consists in applying systematically an appropriate level of caution in research, technology development and transfer, and management, with a view to avoid situations in which the use of the precautionary principle *stricto sensu* would be unavoidable. This line of action changes the status of precaution from an exceptional requirement to an integral part of good management practice.

During the last three years, the concept of precautionary action has become more familiar to fishery management authorities and NGOs who have significantly contributed to the awareness-raising process. The fishery sector's commitment to the approach, however, will still require a lot of effort from both Governments, NGOs and FAO. The approach is now embedded in the outcome of the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks and in the FAO International Code of Conduct for Responsible Fisheries, correcting its omission from the 1982 Convention and the 1984 FAO Conference on Fisheries Management and Development. The detailed Guidelines on the Precautionary Approach to Capture Fisheries, now available in support of the FAO Code of Conduct, will help in promoting its application by States and industry, assisted by the NGOs. In addition, the approach offers the fishing sector the opportunity to request a more responsible behaviour from all those non-fishery sectors which are damaging the marine ecosystem.

The requirement laid down in the UN Convention on the Law of the Sea for the "best scientific evidence available" remains the first condition for effective and equitable management and the concept of precaution does not exempt fishing States and management authorities from their responsibilities to build up the necessary scientific information and cooperation. It seems evident that, in most cases, the State, through its research and management agencies, will continue to be responsible for the establishment of the databases, research and the forecast and assessment of the impacts of its fishery policy (particularly in relation to its coastal and small-scale fisheries). However, in some instances, e.g., in a situation of high potential risk and lack or inadequacy of information, the onus of scientific proof could be put be on industry, e.g., in the form of an Environmental Impact Assessment or pilot project. Expertise is required to support the development of national, regional and international norms of good conduct and advise on the precautionary nature of a proposal in particular situations[37]. The active participation of industry is essential even though experience has shown the dangers of normative systems controlled by industry (Hermitte and Noiville, 1993) and the State must be the warrant of the adequacy of the advisory and decision-making system.

It would not be prudent to forget that precautionary management measures have often been advocated in the past but they have rarely been implemented because of resistance due to their potential short-term costs. The same causes could produce the same effects in the future and it may, therefore, take a decade or so to see the approach as widely applied as recommended in the UN and FAO guiding documents.

[37] A gear might be innocuous in a given ecosystem, under normal conditions, but not advisable in others (e.g, in an ecosystem damaged by other factors than fishing, a series of droughts, an ecosystem in a rebuilding phase, etc.)

Until now, the rationale used (mainly by NGOs) in support of a precautionary approach referred to the risks to the resource and its environment. However, following the economic and social disaster in the Northwest Atlantic, the issue of socio-economic risk to the fishing sector and communities may start taking more relevance as fishermen and governments realize that "future generations" are not only those of the next decades but also those of tomorrow.

The view has become generally accepted, if not yet implemented, in a wide range of fora, that a generalized application of the precautionary approach at all levels of the fishery system, and at all times, is preferable to corrective costly measures rendered necessary by irresponsible development. An effective application of the precautionary approach requires, therefore, a large range of more or less difficult measures throughout the fishery system, its research structure and programmes, its development options and programmes and its management regimes and institutions. The practical guidance contained in the various sections of this paper represent a comprehensive "toolbox" from which elements can be selected to elaborate a precautionary strategy adapted to the various situations. The precautionary level of the strategies so designed will depend on the number and types of precautionary elements selected, the local biological and environmental, economic and institutional conditions, and the type of fishery. The degree of precaution achieved could be assessed as suggested by Kirkwood and Smith (in press).

In summary, a precautionary strategy would have to be consistent with the internationally agreed principles of sustainable development included in the 1982 Convention, the Rio Declaration, the UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks, and in the FAO International Code of Conduct for Responsible Fisheries and would, *inter alia*:

- prohibit any fishing that is not explicitly authorized;
- reflect precaution in the explicitly stated objectives;
- develop an independent and effective research capacity;
- be based on the best scientific evidence, taking account of uncertainty;
- consider all potential management alternatives and their consequences;
- adopt a broad range of management reference points;
- agree on acceptable (tolerable) levels of impact and risk;
- adopt action-triggering thresholds and pre-agree on courses of action;
- integrate them in a management strategy (and management plan);
- aim at preserving flexibility at all levels;
- introduce impact assessment and recurrent evaluation of management;
- implement experimental management and development strategies;
- improve participation (including non-fishery users);
- establish explicit user-rights;
- improve decision-making procedures;
- promote the use of more responsible technology;
- strengthen monitoring, control and surveillance;
- raise enforcement to effectively deterrent levels, and
- institutionalize transparency and accountability.

In designing precautionary management strategies, it will be important to realize that fishermen are part of the ecosystem (as top predators) and that without an appropriate consideration of the risk to their community (both in the short- and long-term), the level of compliance will be low and enforcement excessively costly. This does not mean that when necessary conservation measures appear to be costly they should not be applied. It means, however that, whenever possible, precautionary objectives should be met, minimizing to the extent compatible with these objectives, the costs to the fishing community (including through financial support or compensation). This aspect is of particular relevance for small-scale fisheries and traditional coastal communities which have usually few alternatives to fishing.

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ANNEX 1

DRAFT FAO CODE OF CONDUCT FOR RESPONSIBLE FISHERIES

(Extract from Article 6: Fisheries Management)

6.5 Precautionary Approach

6.5.1 In order to reduce the risk of damage to the marine environment and living aquatic resources, the precautionary approach should be widely applied.

6.5.2 In applying the precautionary approach, fisheries management authorities should take into account, *inter alia*, uncertainties with respect to the size, productivity and state of the stocks, management reference points, levels and distributions of fishing mortality and the impact of fishing activities on associated and dependent species including discard mortality, as well as climatic, environmental, social and economic conditions.

6.5.3 The precautionary approach should be based on the best scientific evidence available and include all appropriate techniques aimed at setting stock-specific minimum standards for conservation and management. Fishery management authorities should be more cautious when information is poor. They should determine precautionary management reference points and apply precautionary measures consistent with management objectives.

6.5.4 When precautionary or limit reference points are approached, measures should be taken to ensure that they will not be exceeded. These measures should where possible be pre-negotiated. If such reference points are exceeded, recovery plans should be implemented immediately to restore the stocks.

6.5.5 In the case of new or exploratory fisheries, conservative measures, including precautionary catch or effort limits, should be established as soon as possible in cooperation with those initiating the fishery and should remain in force until there are sufficient data to allow assessment of any increase in fishery intensity on the long-term sustainability of stocks and associated ecosystems.

ANNEX 2

EXTRACT FROM THE NEGOTIATING TEXT OF THE UN CONFERENCE ON STRADDLING FISH STOCKS AND HIGHLY MIGRATORY FISH STOCKS

(A/CONF.164/13, Article 5, 30 March 1994)

5. In order to protect the environment and the living marine resources, the precautionary approach shall be applied widely by States to fisheries management and exploitation, in accordance with the following provisions:

a. states shall act so as to obtain and share the best scientific evidence available in support of conservation and management decision-making. States shall take into account uncertainties with respect to the size and productivity of the targeted stock levels and distribution of fishing mortality, and the impact of fishing activities on associated and dependent species, as well as other relevant factors, including climatic, oceanic and environment changes;

b. the absence of adequate scientific information shall not be used as a reason for failing to take strict measures to protect the resources;

c. use of the precautionary approach shall include all appropriate techniques, including, where necessary, the application of moratoria;

d. in cases where the status of stocks is of concern, strict conservation and management measures shall be applied and shall be subject to enhanced monitoring in order to review continuously the status of stock(s) and the efficacy of the measures to facilitate revision of such measures in the light of new scientific evidence, and

e. in the case of new or exploratory fisheries, conservative catch and/or effort limits shall be established as soon as possible and shall remain in force until there are sufficient data to allow assessment of the impact of the fishery on the long-term sustainability of the stocks and associated ecosystems.

ANNEX 3

EXTRACT FROM THE NEGOTIATING TEXT OF THE UN CONFERENCE ON STRADDLING FISH STOCKS AND HIGHLY MIGRATORY FISH STOCKS

(A/CONF.164/13/Rev.1 of 30 March 1994)

B. Precautionary Approaches to Fisheries Management

In order to protect the environment and the living marine resources, consistent with the Convention, the precautionary approach shall be applied widely by States and by regional or sub-regional fisheries management organizations or arrangements to fisheries conservation, management and exploitation, in accordance with the following provisions:

a. in order to improve conservation and management decision-making, States shall obtain and share the best scientific information available and develop new techniques for dealing with uncertainty. States shall take into account, *inter alia*, uncertainties, including with respect to the size and productivity of the stocks, management reference points, stock condition in relation to such reference points, levels and distributions of fishing mortality and the impact of fishing activities on associated and dependent species, as well as climatic, oceanic, environmental changes and socio-economic conditions;

b. in managing fish stocks, States should consider the associated ecosystems. They should develop data collection and research programmes to assess the impact of fishing harvesting on non-target species and their environment, adopt plans as necessary to ensure the conservation of non-target species and consider the protection of habitats of special concern;

c. the absence of adequate scientific information shall not be used as a reason for postponing or failing to take measures to protect target and non-target species and their environment;

d. the precautionary approach shall, based upon the best scientific evidence available, include all appropriate techniques and be aimed at setting stock-specific minimum standards for conservation and management. States shall be more cautious when information is poor. States should determine precautionary management reference points taking into account the guidelines contained in Annex 2 (see below), and the action to be taken if they are exceeded. When precautionary management reference points are approached, measures shall be taken to ensure that they will not be exceeded. If such reference points are exceeded, recovery plans shall be implemented immediately in order to restore the stock(s) in accordance with pre-agreed courses of action;

e. in cases where the status of stocks is of concern, strict conservation and management measures shall be applied and shall be subject to enhanced monitoring in order to review continuously the status of stocks and the efficacy of the measures to facilitate revision of such measures in the light of new scientific evidence, and

f. in the case of new or exploratory fisheries, conservative measures including catch and/or effort limits shall be established as soon as possible in cooperation with those initiating the fishery and shall remain in force until there are sufficient data to allow assessment of the impact of the fishery on the long-term sustainability of the stocks and associated ecosystems.

Suggested guidelines for applying precautionary reference points in managing straddling fish stocks and highly migratory fish stocks. (Annex 2 of A/CONF.164/13/Rev.1)

1. Management strategies should seek to maintain and restore populations of harvested stocks at levels with previously agreed precautionary reference points. These strategies should include measures which can be can be adjusted rapidly as reference points are approached.

2. Conservation and management objectives should be stock-specific and take account of the characteristics of fisheries exploiting the stock.

3. Distinct reference points are used to monitor progress against conservation and management objectives. Reference points should incorporate all relevant sources of uncertainty. When information for determining reference points for a fishery is poor or absent, provisional reference points should be set. In such situations, the fishery should be subject to enhanced monitoring so as to revise reference points in the light of improved information as soon as possible.

4. Reference points related to conservation should be chosen to warn against over-exploitation. Management strategies using such reference points should ensure that the risk of exceeding them is low. In this context, Maximum Sustainable Yield should be viewed as a minimum international standard. Conservation-related reference points should ensure that fishing mortality does not exceed and that stock biomass is maintained above, the level needed to produce the Maximum Sustainable Yield. For already depleted stocks, the biomass, which can produce Maximum Sustainable Yield, can serve as an initial rebuilding target.

5. Management-related reference points provide an indicator as to when and how quickly maximum allowable levels of stock removals are being approached. Management action should ensure that such reference points, on average, are not exceeded.

ANNEX 4

DRAFT AGREEMENT FOR THE IMPLEMENTATION OF THE PROVISIONS OF THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA OF 10 DECEMBER 1982 RELATING TO THE CONSERVATION AND MANAGEMENT OF STRADDLING FISH STOCKS AND HIGHLY MIGRATORY FISH STOCKS

(A/CONF.164/22/Rev.1)

Article 6: The Application of the Precautionary Approach

1. States shall apply the precautionary approach widely to conservation, management and exploitation of straddling fish stocks and highly migratory fish stocks in order to protect the living marine resources and preserve the marine environment.

2. States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures.

3. In applying the precautionary approach, States shall:

    a. improve decision-making for fishery resource conservation and management by obtaining and sharing the best scientific information available and implementing improved techniques for dealing with risk and uncertainty;

    b. apply the guidelines set out in Annex 2 and determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded;

    c. take into account, *inter alia*, uncertainties relating to the size and productivity of the stock(s), reference points, stock condition in relation to such reference points, levels and distributions of fishing mortality and the impact of fishing activities on non-target and associated or dependent species, as well as oceanic, environmental and socio-economic conditions, and

    d. develop data collection and research programmes to assess the impact of fishing on non-target and associated or dependent species and their environment, adopt plans as necessary to ensure the conservation of such species and protect habitats of special concern.

4. States shall take measures to ensure that, when reference points are approached, they will not be exceeded. In the event that such reference points are exceeded, States shall, without delay, take the additional conservation and management action determined under paragraph 3(b) to restore the stock(s).

5. If a natural phenomenon has a significant adverse impact on the status of straddling fish stock(s) or highly migratory fish stock(s), the relevant coastal States and States fishing those stock(s) on the high seas shall, directly or through the relevant subregional or regional fisheries management organization or arrangement, cooperate for the adoption, without delay, of emergency conservation and management measures to ensure that fishing activity does not exacerbate the adverse impact of the natural phenomenon on the stock(s). Such emergency measures shall be temporary in nature and shall be based on the best scientific evidence available.

6. Where the status of target stocks or non-target or associated or dependent species is of concern, States shall subject those stocks and species to enhanced monitoring in order to review regularly their status and the efficacy of conservation and management measures and shall revise those measures in the light of new information.

7. For new or exploratory fisheries, States shall establish conservative conservation and management measures as soon as possible, including, *inter alia*, catch and effort limits. Such measures shall remain in force until there are sufficient data to allow assessment of the impact of the fishery on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment shall be implemented, which, if appropriate, allow for the gradual development of the fishery.

ANNEX 5

REPORT OF THE WORKING GROUP ON REFERENCE POINTS FOR FISHERIES

MANAGEMENT[38]

(A/CONF.164/WP.2 of 24 March 1994)

Technical Guidelines on Biological Reference Points

1. INTRODUCTION

1. The United Nations Convention on the Law of the Sea (articles 6 and 119) obliges States to take measures, based on the best scientific evidence available, to maintain or restore harvested stocks at a level which can produce MSY as modified by relevant environmental and economic factors. In order to accomplish this goal, MSY should be adopted as a limit reference point rather than target reference point as described below. However, for already depleted stocks the biomass which can produce MSY may serve as an initial rebuilding target.

2. Many fish stocks around the world are currently depleted. Improvements in fishing technology have allowed fleet fishing power to increase rapidly and to move quickly from one fishery to another. Maximum Sustainable Yield (MSY) can often be exceeded in the early period of a fishery, resulting in resource depletion, associated ecological changes and serious economic problems. Although this is largely due to the lack of efficient controls, enforcement and compliance, the establishment of a set of biological reference points would contribute to better and more precautionary management.

3. Distinction should be made between limit reference points and target reference points. Limit reference points are boundaries which constrain utilization within safe biological limits and beyond which resource rebuilding programmes are required. Target reference points guide policy makers in resource utilization.

4. Reference points for a given stock are developed from biological models which need to take into account the best possible estimates of all sources of mortality and should incorporate the special biological characteristics of each stock. Therefore, to develop reference points, stocks must be regarded as a biological unit throughout their range of distribution. Information on the state of the resource should cover the entire biological unit for comparison with reference points. This will require the identification of biological units for straddling fish stocks and highly migratory fish stocks.

5. As pollution from land and sea-based sources affects fishery resources productivity and resilience, as well as fishery product safety and quality, management should include not only reference points and measures to control fishing, but also action to promote the reduction and, where feasible, the elimination of pollution and degradation of critical habitats.

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[38] This document is the report of the Working Group on Reference Points for Fisheries Management. The Group agreed that all concepts contained in this document reflect its consensus. However, there was insufficient time available to polish the drafting of paragraph 4 in this report

6. The documents prepared by FAO for the Conference on the precautionary approach and reference points for fisheries management, contains useful information and further guidance on these subjects and should be used in conjunction with the present document.

2. DEVELOPMENT OF MANAGEMENT OBJECTIVES

7. Prior to deciding upon a set of reference points, management objectives must be agreed upon. Reference points are not management objectives; they simply serve as a guide to aid managers in choosing from the range of options open to them.

8. The concept of optimal utilization in the United Nations Convention on the Law of the Sea includes the importance of economic and environmental factors as a basis for setting fisheries

management objectives. However, optimal utilization does not have a simple technical definition and cannot be addressed with a single reference point. Therefore, a set of reference points is needed to take these factors into account, on the basis of the best scientific evidence available and with an explicit recognition of uncertainty.

9. Objectives must be set explicitly in order to be able to assess the success of the management procedures. The setting of objectives should, whenever possible, include the specification of the relative importance of different objectives in the overall policy. As objectives are often not explicitly stated, scientific advice must aim at providing an analysis of management options and their implications for the fishery.

10. There are a wide variety of complex objectives in the development of management policy for straddling fish stocks and highly migratory fish stocks. States may have many, sometimes competing, management objectives. However a fundamental objective for all concerned must be the long-term conservation and utilization of fishery resources and, where feasible, other species of concern. That objective can be achieved, *inter alia*, through a precautionary approach to management of fisheries resources in their ecosystems.

3. TARGET AND LIMIT REFERENCE POINTS

11. A reference point is an estimated value derived from an agreed scientific procedure and an agreed model to which corresponds a state of the resource and of the fishery and which can be used as a guide for fisheries management. Reference points should be stock-specific to account for the reproductive capacity and resilience of each stock and are usually expressed as fishing mortality rates or biomass levels.

12. Two types of reference points, limit reference points and target reference points, should be used. Limit reference points are designed for conservation and warn against the risk of over exploitation. Target reference points are designed to indicate when an objective is being approached.

13. Agreement on the appropriate technically defined set of reference points is a prerequisite for a common approach to the management of straddling or highly migratory resources. By introducing limit reference points for triggering pre-agreed management responses, action may be facilitated when a problem occurs.

14. The fishery management strategy should be developed in a multispecies context and describe the action that is taken as the resource status changes. Management strategies need to be developed for each fishery, including newly developing fisheries and account for the biological characteristics of the resources by the use of appropriate reference points. These management strategies should take into account species belonging to the same ecosystem or dependent on, or associated with, a target species.

15. Provisional limit and target reference points can usually be established, even when data are poor or lacking by analogy with other similar and better known fisheries. In all cases, reference points should be updated as additional information becomes available.

16. For broad application of the precautionary approach to stock conservation, it is important to agree on a minimum international guideline for management. With respect to the use of reference points, an appropriate minimum guideline is to apply MSY as a limit on fisheries. Fishing mortality should not be permitted to exceed the level that would produce MSY and stock biomass should be maintained above the level needed to produce MSY. The choice of target reference points should be made such that there is low risk of exceeding the MSY limit reference point after accounting for all major sources of uncertainty. This guidance should be viewed as minimum and not preclude more conservative management strategies.

4. ACCOUNTING FOR UNCERTAINTY

17. To account for uncertainty, management strategies should be so designed that they will maintain or restore the stock at a level consistent with the selected reference points. Uncertainty always occurs in the advice with respect to the current position of the fishery in relation with the reference points. It is vital that uncertainty be quantified and used explicitly in the analysis.

18. The major sources of uncertainty are incomplete and/or inaccurate fishery data, natural variability in the environment and imperfect specification of models of the resources. Simulation studies which incorporate the expected variability and bias in input parameters and uncertainty concerning the factors controlling stocks should be used to scientifically evaluate management strategies. Results must be interpreted in a probabilistic way to reflect these uncertainties.

19. For a limit reference point, management actions should be taken if analysis indicates that the probability of exceeding the limit is higher than a pre-agreed level. If a stock falls below a limit reference point, or is at risk of falling below it, action on the fishery is required to facilitate the rebuilding of the biomass whether or not the decrease is caused by the fishery or is related to environmental fluctuations.

20. The estimates of the reference points should be continuously revised as fisheries evolve and new information is obtained, particularly in the case of stocks subject to strong environmental fluctuations. Both biological and environmental studies will be necessary to facilitate this updating.

21. To be amenable to scientific evaluation, management plans should specify, *inter alia*, the data to be collected and used for management and their precision, the methods of stock assessment, as well as the decision rules for determining and initiating management measures.

5. LINKAGE TO MANAGEMENT

22. In order to estimate reference points, states should cooperate to promote the collection of data necessary for the assessment, conservation and sustainable use of the marine living resources and develop and share analytical and predictive tools. Precaution should be exerted at all levels of management in, defining data requirements, developing stock assessment methods and elaborating management measures. The need for precaution requires the development of an effective capacity to rapidly take action for resource conservation and management. To facilitate this, the selection of reference points should be flexible to allow for practical approaches to management.

23. To design effective management strategies, the management process needs to be clarified. It should include the specification of management objectives, development of limit and target reference points, agreement on management actions and assessment of management performance with respect to the accepted reference points. Management steps should ensure that target reference points are not exceeded, on average, and that the risk of exceeding limit reference points is low.

24. In some fisheries, the management approach used has had the undesirable effect of deteriorating the quality of the data collected. Management procedures should specifically be designed to reduce uncertainties in the data.

ANNEX 6

EXTRACT FROM THE GUIDELINES ON THE PRECAUTIONARY APPROACH TO CAPTURE FISHERIES

(Lysekil, Sweden, 6–13 June 1995)

The Technical Consultation on the Precautionary Approach to Capture Fisheries, held in Lysekil, Sweden, 6–13 June 1995 (FAO, 1995), elaborated the following statement which could provide a useful operational summary of the approach:

Within the framework outlined in Article 15 of the UNCED Rio Declaration, the precautionary approach to fisheries recognises that fisheries systems are slowly reversible, poorly controllable, not well understood, and subject to changing human values. 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*:

- consideration of the needs of future generations and avoidance of changes that are not potentially reversible;
- prior identification of undesirable outcomes and measures that will promptly avoid or correct them;
- that any necessary corrective measures are initiated without delay, and that they should achieve their purpose promptly, on a timescale not exceeding two or three decades;
- that where the likely impact of resource use is uncertain, priority should be given to conserving the productive capacity of the resource;
- that harvesting and processing capacity should be commensurate with estimated sustainable levels of resource and that increases in capacity should be further constrained when resource productivity is highly uncertain;
- all fishing activities must have prior management authorization and be subject to periodic review;
- an established legal and institutional framework for fishery management, within which management plans that implement the above points are instituted for each fishery, and
- appropriate placement of the burden of proof by adhering to the requirements above.