Precautionary Approach and Tuna Research: Perspective from the 1995 UN Agreement

L'approche précautionneuse et la recherche thonière: les perspectives dans le cadre de l'accord en 1995 des Nations unies

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Introduction

The formal basis, on the global scale, for the application of the precautionary approach to conservation and fisheries management was finalized in 1995. The adoption of the precautionary approach to conservation and fisheries management results from a new strategic thinking about uncertainties in our knowledge of and the resulting risks for:

- fishery resources,
- their environment and
- the related economic and social activities.

The approach is likely to have substantial implications for conservation, fisheries management, technology, operation and research. These implications need to be identified and interpreted from the strategic and tactical points of view in the light of the knowledge on different types of resources and the associated fisheries.

The objective of this paper is to identify and interpret research implications for tuna and tuna-like species from the precautionary approach. Unless indicated otherwise, the research implications outlined in this paper and the citations come from the Agreement for the Implementation of the Provisions of the UN 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. Such a scope of the paper is adopted due to the reasons given in the context of information on the formal basis for conservation and fisheries management (see the next section).

The paper aims at pointing out research implications of the precautionary approach in general terms, providing some ideas rather than at comprehensively exploring all the technical details involved. This is due to a limited space allocated for this and other papers presented at the International Tuna Conference held in Mauritius (Nov. 27 to 29, 1996 and a broad audience (including not only fisheries scientists, but also fisheries managers, policy makers and industry representatives).

As background information, a formal basis for conservation and management of fisheries catching tuna and tuna-like species is pointed out. This basis is common for all highly migratory species (HMS) and straddling stocks (SS), which definitions are mentioned in the paper. The risk of an unacceptable decline of fishery resources is central to the concept of the precautionary approach. Therefore, some background information on the tuna resources and fisheries is given in the paper.

The formal basis for the application of precautionary approach to fisheries is presented. Some general comments are given on the compliance with the approach in a case of fisheries targeting tuna and tuna-like species.

New areas of desired research emphasis resulting from the precautionary approach for tuna and tuna-like species are identified. Reflecting the content of the Agreement, the paper concentrates on new or rarely fulfilled research requirements from the approach, particularly for stock assessment for target species, paying particular attention to reference points. However, the need for basic biological research and data collection is also emphasized, indicating studies of particular

relevance. Such requirements are also addressed for non-target species and the habitat.

The tuna and tuna-like species are further referred to in this paper as *tuna* regardless that some of them are not "true tuna" from the taxonomic point of view. The exception is the section mentioning the definitions of HMS, where proper taxonomic names are used. In the paper, there are frequent references made to *principal market tuna species* or simply *principal tunas*, which are the commercially most important tuna species (albacore, bigeye tuna, northern and southern bluefin tuna, yellowfin tuna and skipjack tuna).

The *non-target species* are defined in this paper as:
- species of by-catches (including discards) and
- those ecologically related (e.g., through predation or competition for the same food and/or the same habitat niche).

Stock assessment is meant in this paper as not only determination of the past and present status of stocks, but also refers to the prediction of future states under different intensities and patterns of exploitation as well as the determination of optimal exploitation.

In the formal documents mentioned in this paper, *conservation* is meant mostly as restrictions of fishing imposed to conserve biological resources and their environment. *Fisheries management* is being associated, in these documents, mostly with restrictions of fishing to optimize the operation of fisheries specifically from the socio-economic point of view. In most cases, to optimize the operation of fisheries from the socio-economic point of view, the associated fishery resources need to be conserved. In other words, conservation usually should be part of fisheries management. Therefore, in the following sections of this paper, fisheries management refers to both conservation and fisheries management in the sense used in the formal documents.

Formal Basis for Fisheries Management

The following documents provide the formal basis, on the global scale, for fisheries management:
– the 1982 *UNCLOS*, i.e., United Nations Convention on the Law of the Sea (Anon. 1983);
– the 1992 *Rio Declaration* on Environment and Development (Anon. 1992);
– the 1992 *Agenda 21*: Programme of Action for Sustainable Development (Anon. 1992);
– the *1993 Agreement* to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas (Anon. 1994);
– the *1995 Agreement* for the Implementation of the Provisions of the UN Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation (in Doulman 1995) and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks;
– the 1995 *Code* of Conduct of Responsible Fisheries (Anon. 1995a) and
– the 1996 FAO Technical *Guidelines* for Responsible Fisheries (Anon. 1996).

The years given above indicate when the documents were adopted, but they are not part of their formal titles. The words in *italics* above indicate how the documents will be referred to further in this paper.

Of particular importance are UNCLOS and the 1993 and 95 Agreements. UNCLOS was entered into force in 1994. Since then, it has been legally binding. The 1993 Agreement was adopted by the Twenty-Seventh Session of the FAO Conference. The 1995 Agreement resulted from the 1993-1995 UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks. The 1993 and 95 Agreements will be also legally binding when they will enter into force.

The Code is applicable to all fisheries, but it is voluntary. Regardless of the different legal nature of the Agreement and the Code, they both provide very similar, if not identical, basis for the application of the precautionary approach.

At the time of writing this paper, the Guidelines were not completed yet. They will likely carry less weight than the Code. Countries will probably use them in a selective way to develop their strategies for the implementation of the Code, including their application of the precautionary approach. Number 2 of the Guidelines concerns the "Precautionary Approach to Capture Fisheries and Species Introduction" (Anon. 1996). It was elaborated by the Technical Consultation on the Precautionary Approach to Capture Fisheries, which was held in Lysekil, Sweden in June 6 to 13, 1995 (Anon. 1995b). The content of No. 2 of the Guidelines exceeds that of the Code for the precautionary approach.

The Rio Declaration and Agenda 21 resulted from the UN Conference on Environment and Development (UNCED), which was concerned with not only fisheries, but the environment and development in general. The resulting Rio Declaration and Agenda 21 are not legally binding. They stress the need for a precautionary approach to ocean development, particularly in chapters on management of coastal areas, resources under national jurisdiction and high seas resources.

National fisheries legislation provide a formal basis for fisheries management on a national scale. It draws on UNCLOS and some other formal documents mentioned above.

It may need to be pointed out that the precautionary approach has some similarities with the precautionary principle (see Garcia 1995). However, the above-mentioned documents as well as this paper refer only to the precautionary approach.

Highly Migratory Species (HMS) and Straddling Stocks (SS)

From the technical point of view, species, individuals of which have a repetitive migration pattern and concentrate in small areas during their migration may be vulnerable to overfishing due to the easy of locating and catching them, even when their density is low. Some neritic species (i.e., those mostly occurring in waters over the

continental shelf) may also be vulnerable to overfishing to some extent due to small areas of their distribution. Oceanic species, individuals of which are scattered and move randomly may be more difficult targets of fisheries. However, it should be pointed out that research, monitoring and fisheries management for oceanic species distributed over large areas and fished by many countries may be difficult. Because of the different nature and degree of difficulties and risks, it may be justified from the technical point of view to distinguish HMS from other species.

There is no descriptive definition of HMS in UNCLOS. The following tuna and tuna-like species are, to some extent, arbitrarily listed in UNCLOS as HMS:

- principal market tunas, i.e.,
  - albacore (*Thunnus alalunga*),
  - bigeye tuna (*Thunnus obesus*),
  - northern bluefin tuna (*Thunnus maccoyii*),
  - yellowfin tuna (*Thunnus albacares*),
  - skipjack tuna (*Katsuwonus pelamis*),
  - southern bluefin tuna (*Thunnus maccoyii*),
- billfishes, i.e.,
  - marlins (several species),
  - sailfishes (several species),
  - spearfishes (several species) and
  - swordfish (one species),
- blackfin tuna (*Thunnus atlanticus*),
- bullet tuna (*Auxis rochei*),
- frigate tuna (*Auxis thazard*),
- little tunny (*Euthynnus alleteratus*) and
- kawakawa (*Euthynnus. affinis*).

Principal tunas and billfishes are certainly oceanic, but the extent to which their movement is directional and repetitive varies among the species. The remaining species on the list above could probably be classified as neritic from the technical point of view.

This leaves the following tuna and tuna-like species not listed as HMS:

- black skipjack (*Euthynnus lineatus*),
- longtail tuna (*Thunnus tonggol*),
- wahoo (*Acanthocybium solandri*), slender tuna (*Allothunnus fallai*),

- butterfly kingfish (*Gasterochisma melampus*) and
- mackerels (*Scomberomorus* spp.).

It should be noted that the black skipjack is not included to HMS regardless of being probably more oceanic than little tunny and kawakawa. The longtail tuna is also not included despite of becoming very important for canning and it is subject of substantial international trade, similarly to the principal market tuna species.

Those tuna and tuna-like species not regarded as HMS, probably constitute straddling stocks. According to UNCLOS, straddling stocks are defined as:

> "stocks or stocks of *associated species* occurring both within the exclusive economic zone and in an area beyond and adjacent to the zone".

The reference to associated species implies that they should be, in principle, treated similarly to target species in terms of fisheries management and research.

Tuna Resources and Fisheries

Tuna fisheries with the exception of those directed at neritic species are significantly offshore. They are very difficult to research, monitor and manage. This is because the associated systems are very complex due to:

- broad distribution of fishery resources and fisheries, including high seas to a significant extent,
- complex migration or movement,
- intensive and dispersed spawning,
- many users with significantly conflicting or different interest,
- high mobility of fleets and
- tuna being a global commodity internationally traded on a nearly global scale.

Billfishes are even more difficult to research, monitor and manage due to intensive sport fishing and because they are caught mostly as by-catches of commercial fisheries.

The resources of tuna and tuna-like species other than those of principal tunas and billfishes are more localized (mostly neritic species) and fished by fewer countries. However, they involve mostly developing countries having a limited research, monitoring and fisheries management capacity. This should be taken into account, considering how the research requirements resulting from the precautionary approach can be fulfilled.

There are relatively few heavily overexploited tuna fisheries (Majkowski 1997). The nature of the biology and economics of tuna fisheries systems is probably a greater contributor to this state than fisheries management. In particular, the very high fecundity, opportunistic behavior, mobility and broad distribution of tuna contribute to their resistance to exploitation. Another factor contributing to such a situation may be relatively low prices of the bulk of catches of principal tunas, which is used for canning.

Many tuna scientists think that such characteristics of principal tunas and the associated fisheries makes them impossible to biologically extinct, admitting that the commercial extinction (i.e., reduction in the abundance to levels at which it is not profitable to continue fishing) may be possible. These views cannot be scientifically proven.

Such a situation may be interpreted as a possibility of maintaining the resources in a relatively good state with little or no active fisheries management. While that was the case in the past, it is not certain that the economy of tuna fisheries will not change, particularly in a long term, to an extent resulting in significantly worsening the status of the resource.

The exception to the relatively good condition of principal tunas are the species of northern and southern bluefin tuna, for which prices for sashimi are extremely high, reaching over US $ 200 per kilogram paid to fishermen at landing. Sashimi is raw fish regarded as a delicacy, particularly in Japan (tradition), but becoming also very popular in other countries. Such high prices provide an incentive to continue fishing even when the density of fish is very low and the cost of fishing very high. Bluefin are also more vulnerable to overfishing due to their concentration in some areas during their migration and limited spawning grounds. With the overexploitation of bluefin, bigeye tuna become vulnerable to a significant overexploitation because it is also very suitable for the sashimi market and it reaches relatively high

prices. Recent increases in surface catches of juvenile bigeye in many areas may further impact bigeye stocks (even now regarded as heavily exploited). They may also affect longline catches of bigeye, which are mostly composed of adult fish. Some other tuna stocks are also fully exploited regardless of being mainly used for canning.

The difficulties with effective conservation of bluefin resources and facilitating their recoveries may be indicative of potential problems particularly with fisheries catching other principal tunas and billfishes, many of which are now not effectively restricted and managed. This needs to be taken into account in the implementation of the precautionary approach.

In addition to the above-mentioned concerns, fisheries directed at tuna and tuna-like species other than the principal tunas are rapidly developing, creating potential fisheries management problems. The severity of this problem is not well known because the status of these resources is mostly uncertain.

Another general concern is a very limited information on the status of non-target species, stocks of which also need to be conserved according to UNCLOS.

The state of global fisheries (i.e., large overcapacity) and resources (i.e., most fully or overexploited) is also a negative factor for the future state of tuna resources, especially taking into account the increasing demand for fish products including those from tuna. Therefore, the precautionary approach is of high relevance to tuna fisheries.

Precautionary Approach

General

The precautionary approach has been closely associated with the concept of sustainable development and sustainable use, recognizing that the diversity of ecological and socio-economic systems may require different strategies (Garcia 1996). It aims at reducing, to some acceptable levels, the probability of occurrence of undesired and/or

unacceptable events, promoting inter-generation equity. It is proposed to be used for fisheries systems, where the level of uncertainties and potential costs of these events are significant and, where the full reversibility may not be ensured. Until now, a rationale used in support of the precautionary approach involved the risk to the resource and the environment. However, after the economic and social disasters in the Northwest Atlantic, the socio-economic risk to the industry and the local communities may provide another justification for the use of the precautionary approach.

The precautionary approach can be concisely defined as:

> "... agreed cost-effective ... actions, ..., which ensure prudent foresight, reduce or avoid risk to the resources, the environment, and the people, ..., taking explicitly into account existing uncertainties and the potential consequences of being wrong" (Garcia 1996).

The definition gives a well balanced concept. A precaution may be associated with a prudent foresight to reduce the risk to the resources, the environment and the people.

Within this concept, the measures applied to reduce this risk should be agreed by consensus and cost-effective (in particular not costing more than they can yield), taking explicitly into account uncertainties and consequences of being wrong. This implies a need to measure uncertainties and to reduce them if this is cost-effective or being more conservative. Therefore, research should play a significant role in the implementation of the precautionary approach, especially taking into account UNCLOS' requirement for the "best scientific evidence available", which remains the basis for the application of the precautionary approach.

Unfortunately, fishery systems are not fully predictable and errors are always likely to occur (Garcia 1996). Therefore, from the operational point of view, a precautionary management strategy would need both a sufficient preventive capacity to avoid predictable problems, and enough reactive (i.e., corrective) capacity, flexibility and adaptability to ensure a safe "trial-and-error" process of fishery development.

Uncertainties in fisheries management advice have been recognized for a long time. In particular, natural variability (including climate changes) has been regarded as a significant source of uncertainty and risk (Garcia 1996). In the 1990's, uncertainties became progressively

incorporated into the stock assessment, in particular using sensitivity analysis. Now, with the formulation of the precautionary approach to fisheries management, it is formally proposed to explicitly incorporate them to the system of fisheries management. However, even before, the concept was applied partly or fully to rationally manage some fisheries. For tunas, quotas annually established by the Inter-American Tropical Tuna Commission (IATTC) for yellowfin tuna in the eastern Pacific may be regarded as precautionary because they restrain a potential increase of catches beyond the magnitude, which would be unacceptable.

However, in most fishery systems, a progressive but systematic and decisive shift towards more risk-averse exploitation and management is advisable to avoid crises and reduce long-term costs to the society (Garcia 1996). On the other hand, unnecessarily stringent and costly measures should be avoided as they would rapidly become counter-productive due to foregone development options, deterring fishery authorities from using the approach as widely as possible and discrediting it among industry (Garcia 1996). Also, without an appropriate consideration of the risk to fishermen and local communities, the level of compliance may be low and enforcement excessively costly. This obviously does not mean that if the necessary conservation measures are costly in a broad sense, they should not be applied. Simply, such cost should be minimized as much as possible.

1995 Agreement

The 1995 Agreement associates the precautionary approach with:

> a requirement of "being *more* cautious when information is uncertain, unreliable or inadequate" instead of using "the absence of adequate scientific information" "as the reason for postponing or failing to impose conservation and management measures".

It imposes an obligation to widely apply the precautionary approach "to conservation, management and exploitation of" SS and HMS "to protect the living resources and preserve the marine environment".

In the implementation of the precautionary approach, account needs to be taken of "*inter alia*, uncertainties relating to

- the size and productivity of the stocks,
- reference points,
- stock condition in relation to such reference points,
- levels and distribution of fishing mortality and
- the impact of fishing activities on non-target and associated or dependent species, as well as
- existing and predicted oceanic, environmental and socio-economic conditions".

The 1995 Agreement imposes an obligation on States to "improve decision-making for fishery resource conservation and management by:

- obtaining and sharing the best scientific information available and"
- more extensively applying "improved techniques dealing with risk and uncertainty".

Annex II of the 1995 Agreement pays a lot of attention to reference points in the context of the precautionary approach. The following two types of reference points are distinguished:

- *conservation reference points* or *limits* and
- *management reference points* or *targets*.

Conservation limits are established to safely restrict the sizes of stocks from the conservation point of view. It is of critical importance that they are not exceeded. The population and fishery parameters associated with the Maximum Sustainable Yield (MSY) are regarded in the 1995 Agreement as the minimum standards for conservation limits for target and non-target species. "For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target." According to the Technical Consultation on the Precautionary Approach to Capture Fisheries (Anon. 1995b), conservation limits may be determined and imposed for:

- recruitment,
- spawning biomass,
- ages/sizes,
- distribution area and/or
- ecosystem effects.

Management targets should aim at optimizing the exploitation from the socio-economic point of view. They may restrict the operation of fisheries further then conservation limits.

The 1995 Agreement imposes an obligation to determine and adopt provisional reference points even for new and lightly-intensive fisheries and those for which information "is poor or absent". It is suggested to do it by using "analogies to similar and better-known stocks." "In such situations, the fishery" should "be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available."

Precautionary reference points should be estimated "through an agreed scientific procedure", "accounting, *inter alia*, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty". It should be assessed and ensured that with proposed management measures:

- management reference points are not exceeded on average and
- the risk of exceeding conservation reference points is very low.

In implementing the precautionary approach to fisheries management, States should "take measures to ensure that, when reference points are approached, they will not be exceeded." Therefore, before reference points are reached, precautionary fisheries management measures should be *pre-determined*, agreed and implemented. "In the event that they are exceeded, States" should, "without delay, take action" "to restore the stocks." "Reference points" should "be used to trigger pre-agreed conservation and management actions." The fisheries management measures should be regularly revised "in the light of new information", especially for stocks of target and non-target species, which state is of concern. Such stocks should be subject of "enhanced monitoring".

Similarly as with reference points, there is an obligation "for new or exploratory fisheries," to "adopt as soon as possible cautious conservation and management measures, including, *inter alia*, catch limits and effort limits. Such measures" should "remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment shall be

implemented. The latter measures" should, "if appropriate, allow for the gradual development of the fisheries."

"If a natural phenomenon has a significant adverse impact on the status of straddling fish stocks or highly migratory fish stocks, States" should "adopt conservation and management measures on an emergency basis to ensure that fishing activity does not exacerbate such adverse impact. States" should "also adopt such measures on an emergency basis where fishing activity presents a serious threat to the sustainability of such stocks. Measures taken on an emergency basis" should "be temporary and" should "be based on the best scientific evidence available."

Specifically regarding "non-target and associated or dependent species and their environment", States should "develop data collection and research programmes to assess the impact of fishing on" them "and adopt plans which are necessary to ensure the conservation of such species and to protect habitats of special concern." The conservation actions mentioned above should apply not only to "harvested stocks" including those, individuals of which are caught as by-catches, but also "where necessary to associated and dependent species".

Compliance with the Precautionary Approach

A comprehensive review of compliance with the precautionary approach for tuna fisheries is beyond the scope of this paper. However, it is rather clear that the extent of the application of the precautionary approach for management of tuna fisheries is limited, but some progress is being gradually achieved. One example of such an application is given in the Introduction section.

At present, there are problems even with an appropriate institutional framework for fisheries management for tunas in some oceans. The creation of the Indian Ocean Tuna Commission (IOTC) will hopefully overcome them for the Indian Ocean. In the Pacific, only in its eastern part, there is operating a tuna fishery body. The likely creation of such a body in the western and central Pacific may improve the situation there. However, it might be more appropriate from the technical point to create a body covering the entire Pacific because of the structure of tuna stocks there. In the Mediterranean region, many tuna fishing

coastal countries are not members of the International Commission for Conservation of Atlantic Tunas (ICCAT), which area of competence includes the Mediterranean Sea. This is now being partly overcome by the recently initiated collaboration of ICCAT with the General Fisheries Council for the Mediterranean (GFCM), which most of these countries are members.

Turning to actual fisheries management, for most stocks, only conservation limits, according to the terminology adopted by the 1995 Agreement are being routinely determined. There is little effort to determine management targets. Most fisheries management measures are recommended and applied after the reference points are exceeded. This causes significant delays in fisheries management actions. In particular, "cautious management measures" have not been generally applied for new or exploratory fisheries. For some fisheries, thought not all for which management measures are imposed, there are significant problems with their enforcement. Also, somehow, there are few attempts to exercise caution with or simply manage fisheries catching non-principal tunas, regardless that their status is significantly uncertain. In general, most fisheries targeting tuna and tuna-like species are not effectively controlled and restricted. This may be regarded as posing a significant or unacceptable risk to these resources, particularly considering the high mobility of tuna industrial fleets on the global scale.

Regarding non-target species, data collections have been initiated in some areas. However, the coverage and accuracy of these collections are mostly very limited due to few observers placed on fishing vessels. Their presence appears to be necessary for ensuring an adequate quality of data. Only for very few fisheries, conservation measures or even plans for them are adopted for non-target species. An evident exception is the initiative successfully undertaken by IATTC for yellowfin fisheries in the eastern Pacific.

Implications for Research

Target Species

Stock assessment in general. - Methods for stock assessment, which is of central importance for the application of the precautionary approach, are relatively well developed for, at least, principal tunas, some billfishes and swordfish in some oceans. They include analyses of the catch-per-unit-of -fishing effort (CPUE) and of tagging data, production modeling (including non-equilibrium models), age-structured models including the so-called Virtual Population Analysis and its extensions.

To better assess stocks, the movement and distribution of fish and fisheries need to be accounted for in addition to a better information on the limits of stocks. This necessitates more research on the structure of stocks and the development of spatial models, which are now becoming more frequently used for tunas (Shomura *et al.* 1995 and 1996). Further progress with such modeling should be encouraged, expecting significant advances as a result of also likely increases in our knowledge of spatial aspects of stocks (see the Basic Biological Research sub-section below).

In the context of the precautionary approach, the application of the so-called integrated models (e.g., Sibert *et al.* 1996; Fournier *et al.* 1996) already applied for a few stocks of principal tunas may be particularly fruitful because they allow a rigorous statistical treatment of uncertainties and statistical testing of alternative hypothesis. These models allow a simultaneous estimation of all unknown parameters from different types of data and information. Unfortunately, such methods are usually very complex, computationally-intensive and their development requires sophisticated programming, statistical and modeling skills. This may hammer their use, at least initially. The development of user-friendly software for their application that is adaptable for different tuna fisheries systems might overcome some problems. Therefore, such work and further development and application of integrated models should be encouraged.

For many stocks, especially of principal tunas, assessment is routinely carried out. The situation may be less satisfactory in the Mediterranean

Sea, the Indian Ocean and parts of the Pacific Ocean where there are no effective international institutional framework for tuna research and management or where there were no such arrangements till recently (see the Compliance with the Precautionary Approach section). The fisheries in the Indian Ocean have intensified relatively recently and this intensification has been followed by more, but still insufficient research effort directed to tunas in this region. Especially with the creation of the Indian Ocean Commission (IOTC), the research progress is likely to continue. Regardless of tuna fishing possibly originating in the Mediterranean Sea, the stock assessment there has been hammered especially by a poor coverage and quality of data. As mentioned in the previous section, the situation in the Mediterranean Sea is improving. However, an acceleration of such improvements in all the areas mentioned in this paragraph are required.

More attention is certainly required to stock assessment of non-principal tunas, especially taking into account that fisheries directed at these species intensify on the global scale. Many of these fisheries and the stocks supporting them are much more localized than those for principal tunas and billfishes. They frequently involve only few developing countries having a very limited research capacity and significantly lacking the technical expertise for stock assessment and for research in general. Such a situation exists to some extent in the Western Central Atlantic (Mahon 1996) and in parts of the Indian and Pacific Oceans. This situation necessitates a consideration, at national and international levels, of how progress can be achieved with the assessment of stocks of non-principal tunas, including the consideration of potential financial support from the involved industries, governments and/or international organizations. Such organizations may also play a further role in providing technical expertise and/or building it up at the national and regional scale.

Risk and uncertainties. – For most stocks, more attention needs to be paid to the consideration and estimation of risk of undesired and unacceptable events and to the determination of and account for the uncertainties involved. In particular, more research effort should be devoted to the examination of reliability of stock assessment methods, taking into account the shortcomings of the assumptions involved as well as the commonly encountered problems with the quality of input data and other input information. In this examination, particular

attention needs to be given to the identification of methods that tend to give a biased indication of the status of stocks, distinguishing those resulting in over-optimistic conclusions. This would allow the selection of appropriate methods for their application in the context of the precautionary approach, depending on the overall risk and uncertainties involved for specific stocks.

A better estimation and account of the risk and uncertainties in the actual assessment of stocks are also required. Particularly for many tuna and tuna-like species other than principal tunas, some billfishes and swordfish, this estimation and account are not adequate for the standards set in the precautionary approach. Specifically regarding the uncertain assumptions adopted in the stock assessment, a broadening of stock assessment may be required to account for alternative hypothetical scenarios even if we know little about them. That has been done, for example, by ICCAT in a case of accounting for a limited exchange of northern bluefin tuna between the eastern and western parts of the Atlantic, in which the abundance seems to be significantly different.

The techniques dealing with risk and uncertainty include sensitivity analysis, modeling, decision theory methods and adaptive management. The extent of application of sensitivity analysis and modeling is improving, particularly for principal tunas. However, decision theory methods and adaptive management are not frequently used, if at all, for tunas. In general, improvements to the existing methods dealing with the risk and uncertainties, development of new methods and their wider application are required because they are central to the concept of precautionary approach. The potential benefits from a wider use of integrated models in the context of the precautionary approach are mentioned above.

The 1995 Agreement imposes an obligation on States to take into account particularly the specific uncertainties listed in the second paragraph of the 1995 Agreement section of this paper. To estimate uncertainties in the size and productivity of stocks, more basic research needs to be directed into their structure (see the Basic Biological Research sub-section below) in addition to stock assessment. The distribution of fishing mortality is very difficult to estimate, especially if its geographical-distribution is implied in addition to its age- or size-distribution because the density of fish needs to be determined.

The latter is difficult, if not impossible for most tuna stocks at present. More effort should be devoted to develop better spatial models and to obtain input information for such models (see below) to allow a progress with the estimation of fishing mortality distribution and the related uncertainties. Comments on the estimation and account of the remaining uncertainties listed in the second paragraph of the 1995 Agreement are given further in this section below.

Management measures. – The requirement stipulated by the 1995 Agreement for a prior determination of precautionary measures for not reaching reference points creates a challenge not only for fisheries managers, but also for scientists. This is because the knowledge of resources and fisheries increases with the development of fisheries (particularly after reaching stages of full- and over-exploitation) if fishery data and other information have been collected for substantially different levels of fishing effort. In fact, for some stocks, it may be nearly impossible to reliably estimate the Maximum Sustainable Yield and other reference points before their full- or even over-exploitation. With the adoption of the precautionary approach, management measures as well as the reference points will have to be determined and imposed with less information than it has been traditionally done. This is particularly the case for fisheries in early stages of their development.

From the technical point of view, consideration needs to be given on how to do it and how to facilitate improvements in the determination of reference points and management measures as such improvements are highly desired and explicitly mentioned in the 1995 Agreement (see the Precautionary Approach section). It may necessitate the determination of, initially, provisional reference points and management measures to be adjusted when more information will become available with further development of fisheries. This information may be obtained through the so-called adaptive management (Hilborn and Walters 1992), facilitating a controlled development of fisheries by allowing more risk to the resource (or being less precautionary) at early stages of fisheries development. The extent of the risk allowed in such development should be determined by the ability of potentially reversing undesired or unacceptable events potentially resulting from taking this risk (see the Precautionary Approach section). The fisheries development should be designed to facilitate the collection of inform-

ation required and specified by scientists for a better determination of reference points and management measures.

Most tuna resources are already exploited, unless their exploitation is not profitable due to little demand for particular species. However, the socio-economic situation may change, stimulating exploratory fishing and/or development of new fisheries. With such a change, there will be a need for providing technical advice on appropriate management measures for such fishing. A basis and methods for generating such an advice will have to be established. One obvious possibility would be to use analogies to other well-known stocks and fisheries of similar characteristics.

Reference Points. – Turning to a specific aspect of stock assessment, more research effort needs to be devoted to the determination of reference points for tuna fisheries. At present, contrary to the Agreement, these points are determined not for all fisheries. More consideration also needs to be given to most appropriate types of reference points in the context of requirements of fisheries management. It seems that there is a potential for broadening them beyond the classical MSY, which seems to be still predominantly used.

Reference points for tunas probably should involve the spawning biomass rather than recruitment. This is regardless that also recruitment was suggested by the Technical Consultation on the Precautionary Approach to Capture Fisheries (Anon. 1995b) to be also used for fish stocks in general. This is because recruitment is more difficult to monitor and the stock recruitment relationships particularly for tunas are significantly uncertain. Shrinking distributions of intensively exploited stocks and changes to the distribution of sizes, weights or ages could possibly be more utilized as conservation limits than it is done at present.

The 1995 Agreement imposes an obligation to account for sources of all mortality of fish and uncertainties in the estimation of reference points. This account necessitates the consideration of multi-species interactions and environmental impacts, especially those induced by human industrial activities in addition to fishing. Certainly, more research effort is required for that, thought that it may be very difficult to get input information for this account.

The Technical Consultation on the Precautionary Approach to Capture Fisheries (Anon. 1995b) mentions analogies to better-studied stocks as means of obtaining precautionary reference points for new fisheries or feasibility fishing. This necessitates the consideration of reliability and usefulness of such generalizations for tunas.

To estimate management targets, socio-economic data should be collected and analyzed. This necessitates the socio-economic expertise, which most tuna bodies and international programmes do not have at present. In some cases, such data collections and analyses are beyond their present scope. This requires a consideration of most appropriate arrangements for such collections and analyses, taking into account that at least, some of the fishing countries have such an expertise and they collect and analyze socio-economic data.

Simulations of management systems are needed to assess if with proposed management measures,

- management reference points are not exceeded on average and
- the risk of exceeding conservation reference points is very low.

Simulations involving a long time are also required to consider responses of the fisheries system to alternative management actions in the light of inter-generation needs. This brings the question of reliability of such simulations due to extrapolation and propagation of various errors.

Basic biological research. – More basic biological research for most stocks of tunas is also required because it is of critical importance for providing input information for stock assessment. However, research effort in this area needs to be optimally directed to aid in the formulation of fisheries management advice and consequently, the actual fisheries management. The examination of reliability of stock assessment methods and their sensitivity to uncertain assumptions, input data and other information should lead to the determination of most desired areas of basic biological research.

As mentioned earlier, knowledge of the structure of tuna stocks as well as of tuna migration or movement and behavior are of basic importance to stock assessment and such information is highly uncertain or even not available for many stocks. Tagging is now regarded as the most effective, thought an expensive way of getting the information (Shomura *et al.* 1996 and 1996). Therefore, a conti-

nuing development of various types of tags involving the use of high-technology should be encouraged.

The determination of effective fishing effort, age of caught fish, natural mortality (including its dependence on age, sex and possibly other factors) and environmental impacts on stocks and their vulnerability to fishing is also critical for reliable stock assessment.

Data. – Stock assessment heavily relies on long time-series of fishery data. Therefore, more attention needs to be paid within the context of the precautionary approach particularly to the estimation of uncertainties in such data and their impact on results of stock assessment.

The confidentiality of detailed data for commercial and/or political reasons creates a problem with sharing and using the best scientific information, as implied by the 1995 Agreement. Gradually, the situation is improving, including the public release of various sets of data (e.g., Carroci and Majkowski 1996). However, it is still far from being satisfactory. The preparation of and the establishment of formal agreement on detailed requirements for timely release of tuna data on the global scale, accounting for commercial confidentiality of data would assist in obtaining a further progress.

Non-Target Species and the Habitat

The impact of fishing also on non-target species and on the habitat needs to be assessed according to the 1995 Agreement. Such research is even more difficult for ecologically-related species than for by-catch species. Difficulties in studying non-target species result from:

- limited and inaccurate data,
- incidental nature of fishing effort complicating analyses and interpretation,
- mostly impractical tagging and
- more costly and less effective research in general.

Because of the difficulties and the limited research capacity, some compromises may be necessary to achieve a progress with research on the impact of fishing on non-target species and the habitat. Such compromises may be satisfactory because the risk of unacceptable

impact may be smaller for most of these species than for target species due non-targeting at them. Also, most fishing methods for tunas do not seem have much negative impact on the habitat.

A solution may be to identify the non-target species and elements of the habitat,

on which the impact of fishing may be critical and to concentrate research and monitoring on them. More crude empirical indicators and scientific methods with less extensive requirements for input data and other information may need to be used to assess this impact. Such methods may be less reliable, necessitating a more cautious approach to conservation. A close cooperation with the institutions dealing with the non-target species and their habitat as well as additional capacity and expertise may also be required.

The feasibility of estimation of uncertainties in the magnitude of impact of fishing on non-target species may be considered only after the determination of methods for the impact estimation. This is not done in most areas.

Concluding Remarks

The key elements of the precautionary approach for which more emphasize is required can probably be summarized in the following way:

– A conservative approach to fisheries management with conservation being a condition of sustainability ;

– An explicit account of *all* uncertainties in fisheries management or being even more conservative ;

– Without any delay and certainly, prior to reaching precautionary reference points, the determination and implementation of fisheries management plans including the imposition of management measures restricting all fishing activities, using the readily available information and allowing for an adjustment of these plans and measures when more information becomes available ;

– The treatment, in principle, of non-target species in conservation and consequently, research as that of target species ;

– A high attention to the conservation of the environment ;

– An attention to socio-economic considerations.

In a case of rationally managed fisheries, many elements of the precautionary approach were implicitly considered to extent possible with the existing research capacity even before. Now, they need to be considered explicitly and the actions required by the precautionary approach need to be undertaken without any delay.

As mentioned in the Introduction section, the application of the precautionary approach to tuna fisheries is still in an early stage of development. It is understandable, taking into account that the formal basis for this application was formulated only in 1995 and it has not been entered into force. The process of entering into force may take a long time as that was the case with *UNCLOS.*

The application of the precautionary approach necessitates an acceleration of the process of evolution of fisheries management and a broadening of the scope for fisheries management to fully take into account its requirements. Particular problems with the application of the precautionary approach exist in developing countries where the capacity for fisheries management and research is small. It is difficult to increase this capacity and expertise in a short term regardless of potential benefits from such an increase in a long term. Unless this is overcome, the situation will hamper the progress with the application of the precautionary approach to tuna fisheries. This is because even for most stocks of principal market tuna species fished by developed countries, many developing countries are also significantly involved in fishing the same stocks. Without a proper application of the precautionary approach in the latter countries, the overall effectiveness of the application of the precautionary approach may not be sufficient.

The tactical or operational interpretation of the precautionary approach may need to be further development because the approach and guidelines for its application were developed for fisheries in general without fully taking into account the specific situation with different types of fisheries systems. Problems in its application and their solutions may be similar for many tuna fisheries. Therefore, at the ICCAT Tuna Symposium held in Porta Delgata, Azores, Portugal in

June 1996, it was recommended to organize, in 1998, an expert consultation on technical aspects of the precautionary approach to tuna fisheries.

Scientific input is required throughout the entire process of the application of the precautionary approach starting from the determination of strategic and tactical plans for fisheries management, which should be developed and implemented without delay. The approach has been developed, based on science, to facilitate effective fisheries management despite of deficiencies in information. Until now, these deficiencies have been frequently a reason or an excuse for not accomplishing it. The very important role of research in the application of the precautionary approach can be summarized briefly as including:

– the quantification of *all* uncertainties of relevance to fisheries management,

– the reduction of these uncertainties and

– the account of the uncertainties in generating scientific information needed for the provision of fisheries management advice.

The quantification, reduction and account of uncertainties as well as more attention to non-target species and the habitat necessitate an additional research capacity and/or a re-direction of present research effort, possibly resulting in substantial additional costs to the industry and/or the community at large. However, within the context of the precautionary approach, if uncertainties are quantified, reduced and/or accounted for in fisheries management, less conservative approach may be required, benefiting the industry and the community at large. The cost/benefit analysis may be applied to optimize the required intensity of research or research capacity.

Our present knowledge and scientific methods may not allow the estimation of uncertainties with a high confidence. Therefore, our estimates of uncertainties may be too small. Despite of that, an account of the uncertainties to the extent feasible seems be more logical and constructive than ignoring them completely, which is an alternative. Another similar potential problem is related to the recommendation to take into account consequences of potentially being wrong in fisheries management. This is because we frequently do not know how wrong we can be.

One example of the above-mentioned problems may be the quantification of uncertainties in natural mortality of tunas because there is very little basis for it. This is regardless that some results of stock assessment are significantly dependent on these estimates. Another example of not realizing how wrong we may be is the estimation of the life-span of southern bluefin tuna. Now, it appears that this life-span may be twice as long as our previous reasonably well-established estimates regardless that the southern bluefin tuna is one of the best studied species.

The effectiveness of research in providing the information required for the application of the precautionary approach is dependent also on the effectiveness of:

- the other elements of the fisheries management system and
- the functional relationship among all these elements.

This is because research is an integral part of management systems and requires a feedback from the fisheries in a form of accurate and representative data. This feedback is unlikely to be provided if:

- there are imposed, but not properly reinforced regulatory measures and/or
- there is no proper monitoring system for fisheries.

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