

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION  
(of Unesco)

SCIENTIFIC BASIS FOR THE MANAGEMENT OF FISHERIES  
AND THE CONSERVATION OF MARINE LIVING RESOURCES  
UNDER THE NEW OCEAN REGIME

This document was prepared by two consultants, Dr. Sidney J. Holt and Professor Martine Rémond-Gouillon, at the request of the Secretary of the IOC, for the information of Member States, particularly those participating in the work of the IOC ad hoc Task Team to Study the Implications, for the Commission, of the Convention on the Law of the Sea and the New Ocean Regime\*.

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\* After consultations between the Chairman of IOC, the First Vice-Chairman and the Chairman of the Task Team, the name was changed to take into account the adoption of the Convention in December 1982.

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## SCIENTIFIC BASIS FOR THE MANAGEMENT OF FISHERIES AND THE CONSERVATION OF MARINE LIVING RESOURCES UNDER THE NEW OCEAN REGIME

### FOREWORD

In preparing this paper, at the request of the Secretary of IOC, the authors were aware that many - perhaps most - of the scientific aspects of the new UN Convention on the Law of the Sea, insofar as it deals with living resources and their conservation, are of concern to other organizations of the United Nations system, primarily FAO. However, we understood that the IOC, while being an autonomous inter-governmental body within the framework of Unesco, is regarded also as a "joint specialized mechanism" of the several United Nations organizations that are interested in marine science and its applications, and that co-ordinate their activities arising from that interest through the Inter-Secretariat Committee on Scientific Programmes Relating to Oceanography (ICSPRO); that is, UN, Unesco, FAO, WMO and IMO. IOC is also linked with a number of non-governmental scientific advisory bodies (e.g., SCOR, ACMRR, ECOR) and, through them, with the world marine scientific community. In offering suggestions as to some of the scientific questions posed by the UN Convention on the Law of the Sea we have therefore had in mind this focal position of the IOC rather than its operational role as promoter and co-ordinator of international co-operation in specific oceanographic activities and in the provision of scientific services. The authors would like to thank colleagues, especially Dr. G.L. Kesteven and Dr. M. Ruivo for their careful reading of the first draft and for their helpful suggestions, most of which we have tried to incorporate in the final version.

## INTRODUCTION

1. The UN Convention on the Law of the Sea (1) is primarily concerned, in what relates to living marine resources, with the rights of States in defined marine zones and with the patterns and modalities of co-operation among them. The rights are complemented by a complex, but not comprehensive, array of responsibilities. The rules established would, if generally followed, substantially affect, if not determine, the development of fisheries, the pattern of international relations in that process, and the nature of relevant scientific research. They would affect the strategy rather than the tactics of human utilization of marine ecosystems. Overall objectives are defined and some of the conditions for achieving them are specified. The Convention, as would be expected, deals explicitly and implicitly with matters of long-term importance. It gives little attention to criteria affecting day-to-day, or even year-to-year, decisions which are the primary responsibility of individual States and enterprises, and which, in practice, preoccupy administrations. The scope of this paper, concerning the scientific aspects of the exploration for, and the assessment and utilization of, marine living resources, is similarly limited.

2. The new Convention was drafted in a period during which the previously rapid growth of world sea fisheries has slowed until the rate of increase is substantially slower than the rate of human population growth. In that period, the quality of the fish catches for human food has also steadily declined. Some large traditional fisheries - as that for herring in the North Sea - have collapsed. For others, as that for the Peruvian anchoveta, the percentage of the total catch that is reduced to meal for use as a livestock feed supplement has increased. Some huge fisheries, as that for the Alaska pollack in the North Pacific, continue to grow, but there are ominous signals of impending collapse. There are spectacular cases of increase in national catches, as by Chile, but stagnation or decline is more common. So far, optimistic predictions of the potentials of mid-water pelagic fishes and squids have not been followed by large new developments (2). The most rapid development now is for the Antarctic Krill, annual catches having reached over 500,000 tonnes in four years, and still unregulated, notwithstanding the existence of a new Commission of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). This fishery benefits only two countries, which are already the world's two biggest fishing countries, gives mainly a low grade product, and will, if expanded too much and too fast, affect the other marine resources in the region for which krill is the main prey. The value of living marine resources to humans is overwhelmingly as sources of animal protein of generally high quality and, to a much lesser degree, of oil. Their contribution to the global diet, even counting the poultry and other livestock fed partly on fishmeal, is not large (5% of the total protein; 15% of animal protein) and is unlikely ever to be substantially higher than this. But almost everywhere, fish products are, directly or indirectly, welcome sources of nutritious and tasty diversity in diet. And in some countries, and population strata and groups within countries, sea foods are quantitatively very important indeed. In countries as diverse as Japan and the Maldives, fish constitutes much the greater part of the total protein consumption. In other countries, of which Iceland and Peru are notable examples, export of fish products is a crucial source of foreign currency earnings. And in most coastal countries there are communities almost totally dependent on fishing for commerce or subsistence.

Looking beyond the balance-sheet of national benefits or losses, from the changes in the rules of access to waters in maritime zones under national jurisdiction, with consequent re-distribution of catches from those waters, the long-term problems are seen to be: How to maintain world catch levels and even perhaps increase them somewhat? How to ensure that food products from the sea reach those who need them? And how to ensure the vitality, stability and economic well-being of fishing communities, and the continuity of cultures associated with them?

3. Coastal States are enjoined, in the Convention, to promote utilization of the living resources in Exclusive Economic Zones under their jurisdiction. But all States concerned - whether coastal or other - are required to act, separately and collectively, to ensure that each resource should, in the future, be in a state such that it can render relatively high yields, continually and indefinitely. Evidently, the thrust of the 'fishery' Articles in the Convention is towards the conservative use of resources, while providing rules to determine the distribution of material benefits among States. Thus, in its overall objective, the new law of the sea is a codification of what exists in many international fishery conventions which have come into being and been in force over the past half century. It is in accord also with more recent documents, including non-binding declarations, such as the World Conservation Strategy (3), promulgated by the United Nations Development Programme with non-governmental organizations concerned and in collaboration with FAO and Unesco \*. The document in which the Strategy is described claims that "unfortunately most (current) utilization of aquatic animals ... is not sustainable". If this is so, the implementation of the new Convention should contribute substantially to the execution of the Strategy, since the Convention has something substantive to say about all marine living resources wherever they are, except within territorial seas and internal waters of States.

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\* The Strategy defines three specific objectives of living resource conservation: to maintain essential ecological processes and life support systems; to preserve genetic diversity; and to ensure the sustainable utilization of species and ecosystems. With respect to the last, the Strategy has this to say: "The necessity of ensuring that utilization of an ecosystem or species is sustainable varies with a society's dependance on the resource in question. For a subsistence society, sustainable utilization of most, if not all, its living resources is essential. ... The greater the diversity and flexibility of the economy, the less the need to utilize certain resources sustainably - but by the same token the less the excuse not to. Sustainable utilization is also necessary for the rational planning and management of industries dependent on the resources concerned ... Unfortunately, most (present) utilization of aquatic animals is not sustainable".

4. The 'States concerned' with the conservation of particular resources, and with the management of fisheries based on those resources, clearly include coastal States within whose jurisdictions the resources occur, whether or not they are exploiting them, and any other States whose nationals exploit those resources anywhere or different living resources in the same area (Arts. 63 and 118). There is no indication in the Convention that any list of States drawn up by these criteria would be exclusive; therefore, the text does not conflict with precedent established under certain previously negotiated conventions that non-fishing, non-coastal States may have a legitimate interest - the International Whaling Commission is a case in point \*. Such interest may derive from a more general interest in conserving and in the mode of utilizing the planet's living resources and ecosystems, especially those lying wholly or partly outside national jurisdictions. States that habitually import fishery products originating in other jurisdictions have an interest in the continuity and quality of supply, and hence in good management of exploitation; examples are the interest of fishmeal consumers, during the 1960-1970s, in the state of the Peruvian anchoveta stock, and the more recent concern of EEC fur and skin importers for the State of the stocks of harp and hooded seals in the North Atlantic, especially in Canadian waters. A legitimate interest may also derive from the conduct of scientific research by nationals of any State which would contribute to the best available scientific evidence as required by the Convention as a basis for mandatory conservation measures. The Membership of the IOC, as an assemblage of States that are conducting marine research, co-ordinating this activity among themselves and expecting to profit from its results, could have a strong interest in the implementation of the new Convention with respect to the establishment of the scientific basis required for the conservation of living resources, irrespective of the particular interests of individual Member States.

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\* We shall frequently refer in this paper to the IWC. It is probably best known as the organization under whose 'care' many populations of several species of the great whales were greatly depleted, and some nearly exterminated. This failure led to a call for a moratorium on commercial whaling at the United Nations Conference on the Human Environment in 1972. Since then, meetings of the Commission have been the theatre for possibly the most searching examination made by any intergovernmental organization of procedures for living-resource conservation. The matters examined have included: the difficulties of estimating maximum sustainable yields; uncertainties and the establishment of safety factors in setting allowable catches; interspecific competition and the dynamics of predator-prey systems; appropriate management action when the size of the resource and/or its potential yield are unknown; the problems of monitoring stock size and composition under management. At the political and legal levels, the IWC has been notable as an organization in which States that are not now exploiting the resources for which it is responsible, as well as some other international organizations having observer status, have demonstrated their ability and willingness to make important scientific contributions, their desire to see the scientific results applied and, in the case of the non-exploiting States, have exercised their right to participate in management decisions pertaining to living resources which spend at least part of their lives in areas of the high seas.

The only reference in the Convention to the nature of possible interests of States other than coastal and fishing States is in Art. 62, para. 3, which requires that coastal States, in giving to other States' access to their EEZs "shall take into account ... the need to minimize economic dislocation in States ... which have made substantial efforts in research and identification of stocks". It is difficult, however, to envisage any such dislocation other than that which would arise from either current (but not habitual) fishing or from changes in plans to engage in fishing regarding which considerable investments and commitments had already been made.

5. The Convention differs from most existing regional and special 'fishery conventions', and from the 1958 Geneva Convention on the Law of the Sea, in one important way. That is, it provides for conservation of resources regionally or sub-regionally, and goes some way towards dealing with these geographically defined resources as a whole. It is not entirely satisfactory in this respect; the concept of conservation of ecosystems - maintaining their integrity and productivity - as distinct from the conservation of species and stocks, is barely touched. In several places there is reference to the need, in taking measures for the restoration or maintenance of harvested species, to take into account the interdependence of stocks and the consequences to 'associated species'. Similar provisions are incorporated in the Convention on the Conservation of Antarctic Marine Living Resources, which was negotiated and entered into force in the period during which the Convention on the Law of the Sea was being drafted. Such provisions make far greater demands on science than the already considerable demands made by the 'traditional' regulation of fisheries, species by species or stock by stock. Furthermore, these new demands may differ qualitatively from the old; a wider range of biological and related information, and a much deeper understanding of the dynamics of marine ecosystems than has hitherto been thought necessary in practice will be required to meet them. It is in fact far from clear at the moment that the demands can be met, within the constraints of likely research budgets.

#### RELEVANT PROVISIONS IN THE CONVENTION

6. Many Articles in the Convention bear on the conservation of living resources, and on the management of fisheries to that end. However, for the purpose of this review, we focus on a few of them - in fact, on selected paragraphs of those few. These are:

In Part V of the Convention: Art. 61 (all paras.); Art. 62 (paras. 1, 2, 4 (b,c,d,e)); Art. 63 (both paras.); Art. 64 (both paras.); Art. 65; Art. 66 (especially para. 3(a)); Art. 67 (para. 2); Art. 68.

In Part VI: Art. 77 (para. 4).

In Part VII: Arts. 117, 118, 119 (paras. 1 and 2), and 120.

The Convention deals with some Rights, Duties, Responsibilities, Obligations and modus operandi of States and international organizations in accomplishing their objectives in legally defined zones and, within these, meeting the special provisions regarding different biologically defined types of living resources. Here, it is perhaps more appropriate, and certainly convenient, to examine the provisions primarily according to the types of resource.

7. The Convention makes a fundamental distinction between sedentary species of the continental shelf and all other living resources. The former are defined as "living organisms ... which, at the harvestable stage, either are immobile on or under the sea-bed or are unable to move except in constant physical contact with the sea-bed or the subsoil". For the purpose of applying this and related definitions, the shelf is defined as comprising areas that extend throughout the natural prolongation of the land territory of a coastal State to the outer edge of the continental margin or to a distance of 200 nautical miles from the baselines where the outer edge of the margin does not extend to that distance. Where the outer edge is more than 200 miles from the baseline, the legal shelf may not extend more than 350 miles from the baseline or more than 100 miles beyond the 2500-metre isobath.

8. The Convention affirms the sovereign rights of coastal States in the exploration and the exploitation of the sedentary resources of the shelf, but does not identify any duties regarding them. This contrasts with the provision, in Art. 82, para. 1, that coastal States shall make payments or contributions in kind with respect to the exploitation of the non-living resources of the shelf beyond 200 miles. The omission to identify duties and responsibilities of States with respect to the sedentary resources of the shelf contrasts also with such identification with respect to all other living resources, as we shall see.

9. Recent research has unexpectedly revealed that there exist remarkable biological systems in locations beyond the shelf as legally defined, including organisms that are sedentary according to the definition of Art. 77, para. 4. Some of these organisms may in future come to be regarded as 'resources' which are harvestable for some still unidentified purpose. We presume that they would then be subject to the regime for the living resources of the high seas set out in Arts. 117, 118 and, especially, 119.

10. The Convention does not identify the duties or responsibilities of States, coastal or otherwise, regarding the non-sedentary stages in the life-cycles of organisms that are legally considered as sedentary in their harvestable stages. It is conceivable that such stages could themselves in certain cases come to be regarded as harvestable. Any harvesting would presumably be subject to the regimes for the living resources of the Exclusive Economic Zone (EEZ) or of the High Seas, or both, as appropriate. Clearly, co-operation should be called for between States concerned under the regimes for the non-sedentary resources, and those coastal States concerned with the sedentary harvestable stage, if the requirements for conservation of the former, and the presumed national interests in the latter, were to be met. A more likely circumstance is that certain maritime activities of States other than harvesting may affect the harvestable sedentary stages of the resources of the shelf. Activities which affect the non-sedentary stages, and therefore the sedentary stages, might be undertaken in the high seas, on the sea-bed beyond national jurisdiction, in territorial seas, or in EEZs by coastal or by other States in accordance with the provisions of Part V of the Convention. Such activities would be loosely governed by the general obligation of States to protect and preserve the marine environment (Art. 192) and perhaps by other, more specific, provisions in Part XII of the Convention.



11. For living resources other than the sedentary resources of the shelf, the Convention establishes an obligation for States concerned to take measures designed to maintain or restore populations of harvested species at (or to) levels that can produce the maximum sustainable yield, as qualified by relevant environmental and economic factors. In doing this, account must be taken of the interdependence of stocks, of any generally recommended international standards, and of patterns of fishing. With respect to the living resources of the high seas, it is mandatory for the States concerned to design such measures on the best scientific evidence available to them. With respect to the living resources in EEZs, the coastal States are obliged only to take into account the best scientific evidence available to each of them. However, in the latter case, the coastal States concerned are further obliged to ensure, through proper conservation and management measures, that "the maintenance of the living resources ... is not endangered by over-exploitation". This obligation would appear to set a limit to the degree to which a coastal State, in promoting optimal utilization and qualifying the maximum sustainable yield criterion by, say, economic factors, could determine excessively high allowable catches. In taking conservation and management measures for the maintenance or restoration of living resources of the high seas and in EEZs, States concerned are further obliged to "take into consideration the effects on species associated with or dependent upon harvested species with a view to maintaining or restoring populations of such ... species above levels at which their reproduction may become seriously threatened". In all cases "available scientific information, catch and fishing effort statistics, and other data relevant to the conservation of fish stocks shall (regularly) be contributed and exchanged."

12. Within the broad category of non-sedentary living resources, four special categories are identified in the Convention. Particular criteria may be applied to conserve and to regulate the exploitation of resources that fall into these special categories. These criteria modify or supplement the general criteria summarized above. Articles 65 and 120 affirm the rights of coastal States and the competence of international organizations, as appropriate, to prohibit, limit or regulate the exploitation of marine mammals more strictly than otherwise provided for in Parts V and VII of the Convention. This group of animals is not defined, but is usually taken to comprise all whales and dolphins (with the possible exceptions of those few species of dolphins that are known to inhabit only inland or internal waters), seals and sealions, and the sirenians - that is the species of manatees, insofar as they are inhabiting waters to which the Convention applies, and the dugong. In the discussion of these Articles in the UN Conference on the Law of the Sea, it was widely assumed that they can be interpreted as permitting States and organizations to take measures designed to ensure that populations of harvested species are maintained at, or restored to, levels higher than those that can produce maximum sustainable yields, including the prohibition of exploitation so that populations would be maintained at, or restored to, their 'natural' levels. With such an interpretation, Art. 65 would preclude any narrow interpretation of the injunction in Art. 62, para. 1, to coastal States to "promote the objective of optimal utilization of the resources" in the EEZs. Promotion of that objective is not required by the Convention with respect to the living resources of the high seas. The apparent intention of that requirement with respect to the resources in the EEZs is to ensure that, in exercising its right to determine the allowable catch and a surplus of that catch (that part of the allowable catch that the coastal State does not have the capacity to harvest and to which other States must be given access), the coastal State does not prevent all exploitation or restrict exploitation to levels far below that which the resource could sustain.

A waiver of such limitation in the case of the marine mammals would be in conformity with the existing practice of some States; for example, the United States Marine Mammal Protection Act of 1972, as interpreted by the Courts, refers to 'optimal population' which is a population within a range of levels bounded by the natural level to which the population tends when it is not exploited and the level at which it is held if it is exploited so as to give maximum sustainable yield.

13. The second special category of non-sedentary living resources, established by Art. 64 within Part V dealing with the EEZ, is that of highly migratory species. Species within this special category are named in a list given in Annex I to the Convention. The list was compiled evidently with biological considerations in mind, but the requirements for inclusion in the list are not set out explicitly. Some of the species listed are not known to be highly migratory in the biological sense, and as defined in, for example, the Convention on the Conservation of Migratory Species of Wild Animals, while other highly migratory species are not listed \*.

14. Art. 64 seeks to ensure that all States concerned co-operate in conserving and optimally utilizing highly migratory species within and beyond EEZs. The States concerned are defined essentially as those 'whose nationals fish in the region' for those species. The 'region' is, however, not defined. Such definition, here and elsewhere in the Convention, is the subject of another document (Analysis of the Concept of 'Region' in the Informal Composite Negotiating Text, by Maria Eduarda Gonçalves, FAO, May 1978) but it may be observed that it is by no means clear that the boundaries of a 'region' would coincide with the geographical distribution of any particular highly migratory species or any group of them. Nevertheless, it may be presumed that scientific considerations would play some part in the delimitation of the 'region' if the objectives of Art. 64 are to be met. Inclusion of Art. 64 in Part V of the Convention seems to imply that all the species and groups listed in Annex 1 live at least

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\* In the Bonn Convention, now in force, a migratory species is defined as "the entire population of any species or lower taxon .... a significant proportion of whose members cyclically and predictably cross one or more national jurisdictional boundaries". These boundaries appear to include the sea boundaries between zones of national jurisdiction and international waters, and the "range States" to which particular provisions under that Convention may apply include States the flag vessels of which are engaged in taking migratory species outside national jurisdictional limits.

Annex I of the UN Convention on the Law of the Sea includes, for example, all the dolphins - some of which, while migratory in the above-mentioned sense, may not be highly migratory by comparison with the great whales and tunas. But many marine species that are highly migratory by common usage are not listed in Annex I; examples are some of the phocid seals and the sea turtles.

This Annex, like others, is a part of the Convention (Art. 318) and can therefore be amended only by the procedures set out in Arts. 312 and 313. These provide for amendment by simple majority decision of States Parties after the expiry of a period of ten years from the date of entry into force of the Convention, or by consensus of all Parties, a 12-month objection period being allowed in this case. Amendment may not, therefore, be easy or prompt.

partly within EEZs. This is probably true. But the wording of Art. 64 is consistent with an assumption that all these species also live a part of their time in the high seas. That assumption may not be valid. For example, all the Delphinidae are included in Annex I, but it is not sure that individuals of all marine dolphin species spend parts of their time more than 200 miles offshore. If they do not, then conservation of them, and management of any exploitation, would be covered by Art. 63 para 1, which provides for co-operation among States with regard to stocks occurring within the EEZs of two or more coastal States \*.

15. Even if all the species identified by Annex I conformed with the assumption that they inhabit EEZs and the high seas, there are particular populations of at least some of those species that do not so conform. Thus, while some of the species of whales are, by biological criteria, highly migratory, some populations of them are thought to be 'resident' in relatively small areas. Such populations may live wholly in a few EEZs or even in one only. The application of the provisions of the Convention to such species would presumably require substantial and detailed knowledge about distribution and migrations of particular populations, which presupposes the ability to distinguish them. The list of species of fishes in Annex I probably also includes some species particular populations of which do not conform with the general migratory pattern of the species. To them would then apply the same considerations as held for the cetaceans. The species of cetaceans in the seven families listed in Annex I would, of course, also be subject to the special provisions of Arts. 65 and/or 120; there is no apparent conflict between these provisions, although there is no specific reference to action on a regional scale with respect to marine mammals as such.

16. The other two special categories of non-sedentary living resources cover the diadromous species. Of these, the anadromous species migrate to inland waters to spawn, whereas the catadromous species spawn at sea, some of them well offshore, and move inshore or even into inland waters to feed. These species are, therefore, migratory in the biological sense, and some of them are highly migratory. None of them is included in Annex I, so there is no legal overlap between them and the highly migratory species. They are not, however, listed in another Annex, so that the decision as to whether a particular species is diadromous and hence subject to the provisions of Art. 66 - Anadromous stocks - Art. 67 - Catadromous species - is potentially a matter of controversy. This is particularly so since neither term is defined in the Convention. In practice, the problem is far more likely to concern species that might possibly be considered to be catadromous than the anadromous ones, which are few and rather well-known.

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\* It is noteworthy that Art. 63, para. 1, introduces a concept found nowhere else in the Convention in relation to living resources. It enjoins States to "seek to agree upon measures necessary to co-ordinate and ensure the conservation and development of ... stocks ...". The intent of this particular provision is obscure. Further, both Art. 63, para. 1 and Art. 63, para. 2 - which deal with stocks occurring both within an EEZ and in an area adjacent to it - require that States shall seek their agreement "either directly or through appropriate subregional or regional organizations"; yet Art. 64, which is concerned with conservation and optimal utilization throughout a region, requires co-operation either directly or through appropriate international organizations. It is not clear whether this change in terminology has some significance.

17. The Convention envisages that exploitation of diadromous species will, in principle, be permitted only "in waters landward of the outer limits of EEZs" \*.

The only exception permitted is where economic dislocation for a State (other than the State of origin) would result if that State were not able to conduct a fishery for an anadromous stock in waters beyond the outer limits of EEZs. Permitted fishing in waters landward of the outer limits of EEZs includes fishing by all States through or into whose waters anadromous stocks migrate, although, of these, the State in whose rivers the anadromous stock(s) originate(s) - the 'State of origin' - is determined to have the primary interest and responsibility.

18. With respect to catadromous species, Art. 67 explicitly affirms that the other articles of Part. V apply to such harvesting as takes place within EEZs (i.e., not in internal or territorial waters). Thus, in the present context, the purposes of maintenance, restoration and conservation measures specified in Art. 61, paras. 2, 3 and 4, are emphasized. Art. 66 does not deny the corresponding application of the other Articles to anadromous stocks, but neither does it affirm it. This is presumably because the Convention envisages that "measures to renew anadromous stocks, particularly the expenditures for that purpose (Art. 66, para. 3 (c)), may be taken by States concerned". 'Renewal' seems to imply positive intervention by humans - essentially by ensuring access to rivers and other suitable conditions for reproduction, in which case the concept of a stock having a naturally determined maximum sustainable yield is not valid. By contrast, the only action, other than regulation of catch, envisaged by "a coastal State in whose waters catadromous species spend the greater part of their life cycle" is to "ensure the ingress and egress of migrating fish", and there is no reference to expenditures for this purpose. In practice, the efficacy of such action would affect the sustainable yields of the species, but not so directly, nor possibly to such a degree, as would coastal-State action with respect to migrating anadromous stocks. Thus, the maximum yield concept may be virtually as applicable to catadromous species as to the non-migratory species to which Art. 61 is primarily directed.

#### SCIENTIFIC IMPLICATIONS OF THE PROVISIONS

19. The Convention pre-supposes that it is feasible to identify and categorize species and stocks, to determine the distribution and migratory pattern of each of them and to determine for each a level or levels that could sustain maximum yields. None of these tasks is trivial. The Convention offers no guidance if it should turn out that any of them are impossible to complete, nor does it provide rules for action during any period while these tasks are being performed. This may be an important weakness. Since they are not specified in the Convention, such guidelines and rules will necessarily be developed ad hoc in the context of bilateral, regional and other international arrangements envisaged in the Convention. Considerable divergence of practice can therefore be expected. Similar problems will arise in the procedures to take into account known or likely uncertainties in distinguishing and assessing stocks. The ability of

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\* The distinction made in the text between conducting fisheries for anadromous stocks and harvesting of catadromous species does not appear to have any operational significance.

scientists to perform the required tasks may have been vastly over-estimated by those who drafted the Convention. The difficulties lie not only in the availability of data, as has sometimes been supposed, but also in deficiencies in current methods of evaluating data. After several decades of growing confidence in the ability of the scientific community progressively to improve assessments of exploited populations of fishes, marine mammals and the like, previously obscure biases and uncertainties are being exposed in a number of situations. Examples of these are described below.

20. Further scientific tasks imposed by the Convention are: the analysis of the interdependence of stocks; the identification of serious threats to reproduction of species which are associated with, or dependent upon, harvested species; assessment of the conditions that will ensure that the maintenance of the resources is not endangered by over-exploitation; the identification of relevant environmental factors which may qualify the maximum sustainable yield and the assessment of such qualification. To fulfil these tasks it will be necessary to ensure the systematic acquisition of data of kinds that have been obtained in the past only haphazardly, if at all, and to develop and test new methods for deriving from such data conclusions useful for the purposes specified. The latter will call for the vigorous pursuit of studies that have already begun to transform research on living resources: the mathematical modelling of complex systems; the use of stochastic models where deterministic models have previously been used to assess even those systems that were presumed to be simple (or, rather, could be treated as if they were simple to a first approximation); the application of computers to examine the properties of models and to simulate the consequences of a variety of human actions and of natural changes. Work on the assessment of marine stocks has rested until now to a very great extent on data derived directly from the fisheries themselves - starting with statistics of catches and fishing effort, and including the analysis of size and age distributions. There are indications that basic catch statistics may be worsening in quality, rather than improving, as a direct result of the implementation of the new law of the sea. And the common assumptions that catch compositions are rather simply, or at least predictably, related to the corresponding population structure, are everywhere being shown to be invalid and misleading. Thus, it is becoming apparent that not only must special efforts be made at least to maintain the quality of basic fishery statistics, but stock assessment methods must rely more and more on the results of direct research on the resource - by acoustic and visual observation, for example, rather than on catch analysis. It must be said that such work - and other studies defined earlier - are barely beginning in relation to marine living resources. The beginning happens to have coincided with the collapse of a number of important fisheries, in some cases with virtually no warning. These can mostly be attributed to inadequacies in management, to which poor - even misleading - scientific advice has contributed. If such disasters are to be avoided in the future, as exploitative and other pressures on marine life increase, there will need to be a very substantial improvement in the quality of scientific advice available, and soon.

21. Categorization of resources in the terms of the Convention offers few scientific problems. Application of the definition of sedentary species of the shelf has occupied some biologists and fishery administrators since its inclusion in the 1958 Convention on the Continental Shelf. Most practical

issues have been resolved one way or another, if somewhat arbitrarily. Possible future problems are indicated in para. 9 above. If and when these, or others unforeseen, arise, we may be sure that speedy resolution of them will depend upon the availability of a fund of scientific knowledge about the life cycles of species that are sedentary in those stages that are at present harvested, or are harvestable. Information that could be particularly relevant would pertain to the distributions and abundances of non-sedentary stages in the life cycles, the movements and mobility of those stages, their trophic relations (particularly what they eat and by what they are eaten), and the processes that determine the natural mortality rates between the non-sedentary and sedentary stages, especially the density-dependences of these and their temporal variability.

22. There are in the literature of general biology, marine affairs and fishery science many formulations of definitions of the terms 'anadromous' and 'catadromous'. One such is 'Forms of life cycle (among fishes) in which maturity is attained in the ocean and the adults ascend streams and rivers to spawn in fresh water (anadromous) or in which maturity is attained in fresh waters and the adults migrate into the ocean to spawn (catadromous) (4) \*'. Salmons and shads are commonly cited as examples of the former category and the common ('freshwater') eels, of the latter. Not all stocks of all species of salmons spawn in fresh water, strictly defined; some can and do spawn in brackish or even saline waters. Human intervention, through acclimatization programmes and genetic manipulation, can modify the environmental requirements for successful reproduction by these fishes. However, any spawning in the marine environment by animals of natural or artificially created stocks will surely take place landward of the inner boundary of the EEZs, so that difficulties should not arise with respect to jurisdiction and rules of exploitation as far as the new law of the sea is concerned. A possible exception could arise if proposals for large-scale introduction of salmons into the Southern Ocean ecosystem were to be implemented (6). One problem is a legal one, arising from uncertainties as to the juridical status of the waters surrounding the Antarctic continent. Another may be uncertainty of homing by prospective spawners to States in whose rivers the created stocks originate - they may not originate in rivers, and different batches of introduced animals may not be readily distinguishable from each other. A more important problem would arise from the fact that economic production from such introduced stocks would derive biologically from the secondary productivity of a system which is already being exploited at several trophic levels - krill fisheries, whaling, fishing for finfish that are predatory on krill or on

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\* It has been pointed out (5) that definition of these groups needs clarification because, inter alia, "an extended definition (of 'anadromous') could cover all marine species breeding on land or exclusively in waters under the jurisdiction of coastal States, whereas Art. 66 uses only rivers as a criterion of origin.... Thus estuaries would probably be covered but not coastal lagoons." De Klemm (5, p. 191) remarks that the situation of sea turtles is very similar to that of anadromous fishes. "Coastal States may incur considerable costs to protect beaches where turtles lay their eggs, set up hatcheries and carry out breeding programmes. Yet, if the turtles are caught on the high seas, these efforts will have been in vain." A similar argument could be made for species of pinnipeds (seals, sealions and fur seals). We agree with the recommendation ((5) p. 409) that a scientific group should be established to examine such matters and propose listings of diadromous species, and that this group might also review the listings of migratory species.

some of its predators. Serious consideration is being given by some States and enterprises to exploitation of krill-feeding birds (penguins) and seals. But the same problem already exists in the northern hemisphere, where salmon undoubtedly feed, on the high seas and in EEZs, on species that are themselves harvestable, or are the young of harvested species, or form part of the diets of other harvested species. In general, some of these types of problems are addressed by paras. 3 and 4 of Art. 61 and both sub-paras. of para 1. of Art. 119. The application of these provisions to take account of the interdependence of stocks and effects on species associated with, or dependent upon, harvested species cannot fail, however, to be modified by the fact that the presence and abundance of the anadromous species will be determined mainly by the costly actions of the States of origin. In terms of the rational utilization of the biological productivity of the open sea, there is much in favour of attention to species that have high unit value and are easy to harvest and to monitor. As the net costs of offshore fishing increase as a result of relative increases in energy costs and fishery-caused declines in the abundance of wild harvested stocks, the eventual economic viability of the enhancement of anadromous fish resources will become more likely.

23. There is greater uncertainty about the identity of catadromous species than about anadromous stocks. Although some of the eels are often considered typical of the former category, they present in reality a very special case. The grey mullet, Mullus cephalus, is one of the fin-fish species commonly regarded as catadromous, and it and others support important fisheries. It enters rivers and estuaries, and when it does it certainly feeds there. More often, it enters and feeds in brackish coastal lagoons. But such catadromy appears to be facultative rather than obligatory as is that of the eels, and the anadromy of salmon. Perhaps all other catadromy is facultative. Individuals and, perhaps, whole populations (stocks) of such 'catadromous' species can probably survive without ever entering rivers or even any inland or internal waters, and we know little about where they spawn and what conditions determine reproductive activity. These species are among those that have attracted the attention of scientists seeking to enhance wild stocks and create domesticated ones through the practice of artificial fertilization and husbandry. Because costs fall on the State that may practice such forms of aquaculture, it seems appropriate that Art. 67 should apply to husbanded stocks of such species - even though, unlike Art. 66, it is formulated to deal with species as a whole - for the same reason that is implied in Art. 66, para. 3 (c), referring to 'renewal'. Art. 67, para. 1 gives encouragement to coastal States in whose waters catadromous species spend the greater part of their life cycle to advance specific forms of aquaculture. The 'greater part' can presumably not merely be interpreted as 'greater time', but also as a reference to the performance therein of all biological functions, primarily feeding and reproduction. Thus Art. 67 should give impetus to research on those functions and on natural and human threats to them, as well as on the causes of mortality of the young in the open sea.

24. Annex I does not include some of the most 'highly migratory' of all animals - the marine turtles - and it is also not clear that stocks of them could be regarded as anadromous under the Convention. We suggest that a committee of scientists should be involved in any amendment procedure for

the Annex. They go so far as to say that "new scientific evidence will (presumably) sooner or later raise questions about the adequacy of this listing." This implies that significant scientific questions are involved. That would appear to be so, but the precise nature of these questions is not obvious. In their approach to the regulation of fisheries based on stocks that live both within one or more EEZs and in adjacent areas of the high seas, Articles 63 and 64 appear to differ only in that co-operation among coastal and fishing States through international - essentially regional - organizations is mandatory in the latter case (EEZ) and optional in the former (high seas). There are, it is true, other small differences in formulation. Art. 64, but not Art. 63, speaks of "promoting the objective of optimum utilization", whereas Art. 63 speaks of ensuring the "development" of stocks that occur in the EEZs of two or more coastal States, but has no reference to such a requirement for stocks that occur also in the adjacent high-seas areas. The intent of these provisions is obscure; one can only suppose that 'development' implies some intervention by coastal States positively to enhance the biological productivity of the resources common to them, much as is implied by 'renewal' in the case of anadromous stocks. It is noteworthy that, just as we noted with anadromous vis-à-vis catadromous resources, Art. 63 is concerned with stocks, whereas Art. 64 with species. As we have already pointed out, there are almost certainly some stocks of the species listed in Annex I that do not occur in two or more EEZs and the adjacent areas of high seas; nevertheless, fisheries for them would apparently necessarily be regulated through international bodies that are regional in scope. These considerations do not help us see what particular scientific knowledge might apply in any future revision of Annex I. Nevertheless, we associate ourselves with the suggestion that an appropriate group of scientists, possibly under the aegis of FAO, as the appropriate organization within the UN system to deal with fisheries, should examine this matter more deeply, in the light of present marine biological knowledge, and that some scientific body should be given a watching brief on the implications of any new discoveries about migratory patterns and the like, as well as on relevant marine environmental studies.

25. In observing that we can envisage few if any scientific difficulties in determining what animals are marine mammals in the context of Articles 65 and 120 \* we conclude our consideration of the scientific aspects of the problems of identifying living resources in terms of the categories established by the Convention. We now turn to the substantial and scientifically far more difficult problem of determining which Articles apply to each of them with reference to the zones in which they occur.

26. Some marine resources are almost certainly confined to the territorial sea and/or the internal waters of a single State. The Convention recognizes the unconditional sovereignty of the coastal State in these zones as far as living resources are concerned (and, for archipelagic States, in its archipelagic waters) and offers no guidance as to the mode of utilizing such resources. Nor does it indicate what actions are appropriate in those zones regarding resources which are common to them and

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\* Polar bears, which are the subject of an inter-governmental agreement, might be considered by some to be also subject to the new UN Convention on the Law of the Sea, in which case they would be 'marine mammals' in the meaning of Arts. 65 and 120. They are so considered in the national legislation of some countries.



the adjacent EEZ. Yet it is virtually sure that nearly all resources that occur in an EEZ will occur also in the territorial sea/internal waters, or in the adjacent high seas, or both \*. Furthermore, many of the resources that occur in the high seas - perhaps most of them - will occur also in one or more EEZs.

28. The concept of a resource 'stock' pervades the text of the Convention, although there is no specific reference to it in connection with catadromous species and sedentary species of the shelf. There are also numerous references to 'populations of harvested species'. Only in the special provisions for highly migratory species is there no reference to either term, although the applicability of either or both concepts is implied by the specific reference to the applicability of all the other provisions of Part V of the Convention to this type of resource. Now, the problem of defining these two terms operationally in the context of fishery management has occupied the attention of scientists for many years. We cannot attempt here to review or even to recapitulate their discussions and writings. A population in this context is usually taken to mean a genetically distinct and relatively homogeneous group of animals of a single species, interbreeding with each other, sharing a common life-pattern, occupying a particular location (including migrating along common paths) and continuous in time, being self-regenerating. If any entity possesses dynamic properties such as a capacity to provide sustainable yields under certain conditions it is perhaps this. Thus, over the years, it has come to be assumed that, ideally, the regulation of fisheries for wild resources should be based on the recognition of populations and on determining optimal conditions of exploitation with respect to each of them. The term stock has a more varied usage. It is sometimes qualified as a breeding stock, in which case it seems to be more or less synonymous with 'population' as above. But it can also be qualified as a management stock. This is basically a matter of regulatory convenience. It may be convenient because the biological identity of the population being exploited is not fully known; a delimitation of a stock by geographic co-ordinates (perhaps modulated by seasonal considerations arising from migrations) is then taken as an approximation to the population. In other cases, the essential problem is that individuals of different populations, of what may even be the same species, are taken simultaneously in the same fishing gear. The individuals may not be recognizable as belonging to one population or the other, or it may be that there seems to be no practicable way to regulate the catches of each separately. In certain special cases the individuals may be recognizably different and caught separately, but there is reason to treat them as being in separate 'stocks' even though they clearly belong to the same 'population'; a case in point is the treatment by the IWC of the two sexes of the sperm whales in a given population (or what might be called 'binary management stock') as two distinct but inter-related 'stocks'. We shall need to keep such complications in mind as we consider the scientific problems arising from the Convention.

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\* Some resources occur in the internal and/or territorial waters of more than one State, but not in the adjacent offshore zones. Rational utilization of these calls for close international co-operation among the coastal States. The Convention does not provide for this. Such co-operation would call for specific research activities, presumably to be co-ordinated bi- or multi-laterally by the States concerned.

29. The most basic question is the identity of the species of reference. There remain some taxonomic problems: there have been occasions in recent years when what had been thought to be individuals of the same species of fish have been found to be of two or even more species. Such identifications have usually been based on fine differences in morphology and anatomy, but the different species almost certainly maintain their distinctness by having a number of differences in their natural history. Such differences are likely to be reflected in their liability to capture by particular gears at certain times and in certain places, and hence to be relevant to the implementation of the provisions in Articles such as 61 and 119. In other cases, species have been clearly distinguished by biologists, but not recognized in management practice. An example is the sei and the Bryde's whale, which were not recorded separately in catch statistics, nor was catching of them regulated separately, until the late 1970s, even though they live in different places with possibly some overlap. An intermediate example can also be found among the great whales. In the 1960s small blue whales began to be taken in the Southern Ocean. Scientists and administrators from the exploiting country argued that these were individuals of a different taxon (possibly a sub-species) than the 'normal' blue whale. Subsequently, papers were published in the scientific media which justified this assertion, and the biological distinction now seems to be generally accepted. For several years, however, there was some scepticism about this matter; clearly, with the catching of blue whales about to be prohibited because of their depletion, it would serve the interest of those who wished to continue exploitation to claim that they were not taking the young or smaller individuals of the depleted species populations, but rather were now exploiting different biological populations. This example has been described in some detail because it seems quite possible that similar situations could arise in the application of Art. 63 and perhaps Arts. 64 and 119. In such cases it may be necessary to seek to ensure that the normal scientific procedures in the field of taxonomy and systematics are followed, and promptly.

30. Recently, cases have come to light where individual animals could be assigned to different populations, living in the same locations, but among which no anatomical or other major biological differences could be detected. This knowledge has come from the increasing application of techniques for recognizing individual cetaceans in life, by surface features such as coloration and protuberances, by natural deformities or by scars from human or other causes, and even by their behaviour. Such studies have revealed, for example, that, among the southern right whales that winter and breed near the coast of Patagonia, there are several separate populations that have different timing in their live-cycles by virtue of which they probably do not inter-breed. This phenomenon can account for otherwise inexplicable fluctuations in the apparent number of animals in what was previously thought to be a single 'population', if the different true populations differ among themselves substantially in number. In some fisheries for fin-fish, fluctuations have subsequently been explained when it has been discovered that a number of over-lapping species were involved; it seems possible that the situation found for the right whales could exist in other animal species having long lifespans and not necessarily reproducing annually or spawning at exactly the same time or under the same environmental conditions. Research on this phenomenon should perhaps be encouraged.

31. Scientific methods available for the identification of stocks and determining their distributions are very limited. A first step is commonly the mapping of the density of a particular species, either from indices such as catch-per-unit-effort (cpue) or from sampling or acoustic surveys. Typically, these show a pattern of trend from areas close to shore to areas further offshore, and a corresponding pattern of variation roughly parallel to the coast, such that there are relatively high densities near a 'centre' and lower densities towards the edges. Such patterns are complicated by seasonal changes and differences in the distributions of animals of different ages, sizes, stages of development, biological state, and sex. It is a natural assumption that the zones in which a population occurs - one or more EEZs and the adjacent areas - are revealed by these patterns, and that may be so. Furthermore, where two dimensional distributions show two (perhaps more) peaks, separated by a trough or saddle, it might be presumed that this indicates the existence of two or more distinct populations whose distributions overlap in the saddle, which is thus an area of mixing. Unfortunately, identical types of pattern can be, and have been, interpreted completely differently. For example, there appear to be two or more distinct populations of sperm whales living in the North Pacific. Data from marking experiments (see below) seem to indicate this. The large males feed in more northerly waters - where they were mainly caught in the past - and individuals from different stocks mix there to an unknown degree. Determination of a median line, such that any individual caught on or near it is as likely to be from one stock as from the other, is important for the management of exploitation, but it is also crucial for the determination of the sizes and status of the two management stocks and for the calculation of sustainable yields and allowable catches. It has been argued that a peak in a distribution pattern indicates the location of maximum overlap and mixing of two stocks. The same 'logic' has been applied to the minke whales in the southern Indian Ocean. Clearly, if we consider a distribution in one dimension, the sum of two overlapping peaked curves could be a curve with a single peak. But the separation between the components could be such that the summation is a curve with two peaks. If we observe one of those, we should perhaps look for the other one elsewhere. Unfortunately, the distribution and density data usually come from the fishery itself or from geographically incomplete surveys; this is so in the sperm whale example. So the observed peak may show us not the location of a mixing zone, but quite the opposite. Similar problems have arisen in attempts, spanning decades, to define a median line in the North Pacific that may serve as an approximate separator of American salmon stocks. Such data alone, therefore, do not resolve the problem of population distribution and stock boundaries, and can be misleading.

32. A widely used method of studying population identity is by marking individuals in some way and hoping to capture or recapture some of them later. In marking experiments on land, recapture is commonly affected by experimental sampling. In the marine environment, this is virtually never practicable, and recaptures come from commercial catches. Such recaptures commonly show net movements of individuals and as commonly show no great movement. However, these recaptures reveal as much about the distribution of capture operations as about the movements of the marked animals. They may be recaptured in the same area because that is where the fishing is anyway. Recaptures in two or more areas can produce a pattern that appears to show a tendency for the animals to move in a particular direction, but this conclusion might be spurious. Furthermore, the probability that a recaptured mark will actually be reported to the experimenters is usually

not a constant, and may vary greatly from fleet to fleet, especially among different exploiting nations. That, too, is a source of misinterpretation. Marked fish will, in time, die naturally, but they might die at a different rate from unmarked fish, or have a different probability of being captured; they may lose their marks; they may, after being marked, behave differently from unmarked fish. A great deal of research has been conducted on these matters in a few fisheries. If the necessary conditions of experiment and observation are fulfilled, the method is valuable. The new law of the sea should give encouragement to those engaged in such studies. It is evident, however, that success depends not only on good marking techniques, but also on the availability of detailed information about the distribution and effectiveness of fishing operations and on a very close collaboration among participating countries, including full and rapid exchange of release and recapture data.

33. Repeated recognition of individual live animals from natural features has been mentioned as a powerful tool for the investigation of population identity. This will rarely be possible, however. A more general approach is to examine statistical differences, especially of samples from commercial catches. This derives from the assumption that, if two populations of the same species do not, or rarely, interbreed, genetic differences between them will increase. Potentially, an enormous number of characters could reveal such differences, and many have been examined in one situation or another. They include coloration patterns, body proportions, growth rates (though these are subject to easy misinterpretation because growth is so closely linked with non-genetic factors) and, more recently, biochemical characteristics such as blood and muscle proteins and immunological factors. When differences are found, population separation is indicated, and this conclusion is strengthened by the concurrence of several kinds of difference. If no differences are found, this does not, of course, mean that there are none, or that there is only one biological population, although such a conclusion has sometimes been reached erroneously. But in practice it is frequently extremely difficult to obtain statistically clear results from these methods, and much controversy has surrounded the conclusions drawn from them. The need is urgent not only to refine further the techniques of data acquisition (including the examination of behavioural and physiological characteristics, as well as morphological and biochemical ones), but also to improve the methods of interpreting the data.

34. When a terrestrial animal population is reduced by hunting, or by adverse environmental conditions, a change in its area of distribution is often observed. This might be a contraction, with density remaining relatively high in the environmentally most favourable areas. Alternatively, a greatly depleted species may thrive only in naturally less favorable areas, further from human activities. There can also be changes in distributions as a result of changes in the distribution of favorable environmental conditions. Such changes may be climatic in origin, or related directly to biological factors that determine the well-being and survival of the species in question. We know very little indeed about changes of all these kinds in marine animals, yet they could be of great practical significance for us, including the application of the Convention in certain cases. It is known that there have been medium- and long-term changes in the distribution of commercial fish species in the North Atlantic, probably associated with oceanographic and climatic change.

These would have altered their availability in different EEZs if such zones had then existed. Availability can, of course, also change with year-to-year variations in ocean conditions. Both kinds of change will need to be accommodated in the application of the Convention, and this will be difficult without much more scientific information than we now possess. Contractions in distribution accompanying reductions in population size could effectively alter the management patterns under the Convention with respect to zones in which populations effectively live. Such contraction, if it occurs, could also profoundly affect estimates of the size of the population based on the apparent density of animals in the preferentially fished parts of the total area. Lastly, in those cases where distribution of the species has already been drastically changed by over-exploitation, leading to remnant populations surviving in only a part of the total area which is accidentally or deliberately protected from human activity, effective application of para. 5 of Art. 194 referring to the protection of the habitat of depleted, threatened or endangered species, becomes supremely important. For all these reasons, research on the factors that determine the distributions of marine animals is important for the new ocean regime.

35. The question of whether, when population identities are not well known, it is practically desirable to establish one or a few 'management stocks', by 'lumping' two or more of them, or by 'splitting', has engaged the attention of fishery scientists and administrators for many years. In certain cases there has been a tendency to act on the assumption that 'splitting' is more conservative in its effect, within given regulatory procedures. In that way, it is argued, one of two or more possibly distinct populations, is less likely to be depleted unwittingly through the application of an overall allowable catch. There are, however, circumstances in which such an assumption is not necessarily conservative. Where knowledge of the dynamics of the resources is inadequate, substantial exploitation might be permitted on one of the split management stocks, while it is more limited or even temporarily prohibited on the others, when in fact, if knowledge were better, stricter limits would be set for all of them. Such cases have arisen in the IWC, and elsewhere. There is a clear need for more study, principally by modelling or simulation, to establish optimal measurement strategies in uncertain circumstances, including the definition of management stocks pro tem.

36. It is now time to move to the next, equally important, provisions of the Convention - those referring to the design of measures to maintain at, or restore populations to, levels that can produce the maximum sustainable yield (MSY). The MSY concept has in recent years been the subject of much critical comment by scientists and economists. Some of the reasons why it is considered a less than adequate criterion for management are summarized in (7). These reasons arise from economic, biological and practical considerations. They include the following:

- (a) a maximum net economic benefit may be obtainable when a stock is kept well above its presumed MSY level;
- (b) the MSY and the corresponding stock level may be very difficult or even impossible to determine; great uncertainty attaches to all estimates;

- (c) MSY may not be a constant, but rather a function of varying environmental conditions, including the relations between the population in question and its food supply, competitors and predators;
- (d) compensatory mechanisms within a species population are such that, although a range of sustainable yields is possible, the maximum of these is at a level so close to the unexploited level that it is not a practically useful objective.

Such considerations have led to the formulation of alternative sets of criteria for conservative exploitation (8,9). These have not yet all been expressed in operational form, but some of them are explicit, and others implicit in the Convention. They include the needs to avoid irreversible consequences of exploitation or of other human activities, to qualify the basic criterion by relevant environmental and economic factors, and to take into consideration associated or dependent species. Some of these are also already covered by international fishery regulatory instruments; examples are the provision for safety factors against uncertainty in the New Management Procedure for the IWC, and the specific provision for effects on associated and dependent species, in the Convention on the Conservation of Antarctic Marine Living Resources \*.

\* Article II of the Convention is as follows:

1. The objective of this Convention is the conservation of Antarctic marine living resources.
2. For the Purposes of this Convention, the term 'conservation' includes rational use.
3. Any harvesting and associated activities in the area to which this Convention applies shall be conducted in accordance with the provisions of this Convention and with the following principles of conservation:
  - a. prevention of decrease in the size of any harvested population to levels below those which ensure its 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 increment.
  - b. maintenance of the 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;and
  - c. 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 impact of harvesting, the effects of environmental changes, with the aim of making possible the sustained conservation of Antarctic marine living resources.

It may be noted that sub-para c. of the same Article of the CCALMR would have application to the proposed introduction of salmon, as an alien species.

37. With respect to (a) above, it has been pointed out (a) that whether this condition is met depends on the rate at which future values are discounted in the economic calculation; if this rate is relatively low, it may well be true but the higher the discount rate the more likely it is that the 'optimal' economic return, over time, will be obtained from stock levels lower rather than higher than the MSY levels. What matters is actually the relation between the discount rate and the natural growth rate of the population. In fact, when, as in the case of whales and other at best slowly increasing species, the discount rate is relatively high, it could be economically optimal not to exploit the species population sustainably at all, but rather virtually to exterminate it at a controlled rate. However, against this, it has been argued that, if this is so, then economic theory does not give acceptable criteria for rational management. Recently, an intermediate view has been expounded. The author of (10) argues that "utilitarian theory mandates a specific policy with respect to renewable resources, ... the biological structure of which allows us to transform the theoretically intractable problem of estimating the distant consequences of an action on them into a scientifically difficult but theoretically tractable problem of estimating its contemporary consequences". Further, "this transformation is accomplished not by using the dubious (and in some cases obviously false) assumption that the distant consequences are negligible, but rather by using well established biological theory to show that no policy we could follow would give distant generations a heritage of renewable resources with more expected utility than a maximum sustainable yield policy". Now, the biological theory may not be so 'well established' as she believes. She uses a very simplistic population model in the analysis, by which she reaches the above-mentioned conclusions, although it does not seem that a more complex and realistic model of the same general kind would lead to substantially different conclusions. But there clearly is scope here for fruitful collaboration between natural scientists, economists and political scientists to examine such questions more deeply, since an understanding of them could enormously influence the future role of humans within the biosphere.

38. There has been considerable discussion of the appropriate units in which to express MSY. Most calculations in the field of fisheries have referred to the total weight of fish in catches from a stock, annually. The Convention does not specify a temporal scale for the determination of allowable catches, and although it is often assumed that this should be yearly, it need not be, nor is that always the most appropriate periodicity. For several stocks, the exploitation of which is regulated by the IWC, catch limits have been set as total over a period of several years, usually with a provision that not more than a certain quantity may be taken in any one year. This approach has usually been taken in the absence of what scientists could agree to be reasonable stock assessments. The so-called 'rolling limit' is said to avoid the penalization of the exploiting industry in years in which the accessibility of whales to the operators is unusually low. It could equally be applied where the abundance of the stock fluctuates substantially, as a result of variability in recruitment, but where the fluctuation cannot be predicted either by monitoring the pre-recruit animals (those not yet quite old or large enough to be caught) or from theoretical considerations. A similar practice has been established where the same exploiting operation is carried out on adjacent management stocks of the same kind; an area allowance is granted, for each regulatory period, whereby a total catch limit is set for all stocks, but the catch from any particular one of them may exceed its nominal limit by a certain amount or percentage. The implications, for rational management, of such procedures need further study.

39. MSY is usually expressed as total weight of catch, although with marine mammals an allowable number, if traditionnally specified, is accepted. The IWC Scientific Committee has, on numerous occasions, pointed out that the value of the catch is more closely related to its total weight than to the number of animals comprising it. The differences are quite substantial when growth of individuals occurs after the size or age at which they first become liable to capture. There has been much confusion over the possible form of regulation designed to maximize sustainable catch by weight. Evidently, it is not in general necessary for the allowable catch in such cases to be specified by weight; it may be virtually as satisfactory to specify a number that will maximize weight, if implemented at the same time as a minimum size limit. In fact, however, the total value of the catch is rarely directly proportional to its weight, either for fishes or marine mammals, because individuals of different sizes may attract different market prices per unit size \*.

Furthermore, the distribution of relative prices can vary considerably from one exploiting country to another, and the management regime, by affecting the sizes of the catches and their composition, can itself affect price levels and their distribution. It is generally conceded that, in international practice, such considerations cannot effectively be taken into account. When we come to examine the problem of applying the maximum yield concept to two or more interacting species, however, we see that the questions of relative values of, say, a fish species and its commercially valuable prey, cannot be avoided - there must be either an explicit or an implicit recognition of the usually very different economic values of the species concerned. Enough has been said, we think, to indicate a general area which calls for further examination jointly by biologists and economists.

39. Art. 61, para. 3, and Art. 119, para. 1(a), of the Convention refers to population levels that can produce maximum sustainable yields. But the conditions for a maximum include more than an appropriate population size; they include appropriate population structure, as defined, at least, by size and age composition, the proportion of mature and immature animals, and the ratio of the sexes. The models used for the estimation of population parameters and for predicting sustainable yields are usually applied to determine an MSY level, and the other characteristics are implied. If the level is correctly maintained but the population structure is not optimal then the stock can change substantially if Total Allowable Catch is set at or near MSY. In particular, from the point of view of 'avoiding endangering the maintenance of the resources by over-exploitation', it becomes essential to determine that the structure of the population is not such that, even if its number is optimal, it will nevertheless decline if the catch taken from it over a period is close to the theoretical MSY. Cases are even known where a population is greater in

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\* An extreme case is found in North Atlantic sealing, where by far the most valuable products are the skins of harp and hooded seal pups. Here it has also been argued that it is necessary to reduce seal populations to permit improved catches of fish species, such as capelin, on which the seals in part feed. There is little scientific evidence for such action, but, even if there were, the fact is that the prices of fishmeal (from capelin) and seal fur are determined by completely different and independent market factors, and are both extremely variable, so that no economic commensuration is feasible.



number than the estimated MSY level but its structure is such that it is predicted to decline if only small catches are taken, or even none at all. The concept of 'MSY level', which the Convention reflects, comes in fact from simple population models which are now rarely used by specialists in this field of research. The knowledge of population structure required to meet the evident conservation intent of the Convention requires far more biological information than is suggested by the references to catch and effort statistics in Art. 61, para. 5, and Art. 119, para. 2. Admittedly, in both places, the phrase "and other data relevant..." is inserted. However, experience in international fisheries conventions is that there is a tendency to specify fewer types of data exchange than are actually necessary for assessments. There is, therefore, a clear need for scientists to specify exhaustively what are the necessary data for a given state of the art of population analysis. Then, those responsible for implementation can ensure that it is mandatory to collect and freely exchange such an array of data in all situations where international co-operation is required under the Convention.

40. In recent years, it has come to be understood that the minimum necessary information (though not usually in itself sufficient) comes from the application of particular techniques in a sampling procedure. The techniques in question are those to determine the ages of individual animals, and their sexual states. Problems in application arise from consideration of the suitability of the sampling procedures and from the inherent uncertainty of techniques. Two examples of uncertainty are that individual age can be determined from hard structures only with error - which might be in part measurable - and that the stages through which an organism develops may be identifiable but the durations of those states not well-known, or variable with environmental factors. It has usually been assumed that such factors - at least those of the first kind - add to the error of assessments but not substantially to the bias in them. Recent studies have suggested that this latter assumption may not be valid; that, in fact, bias can be substantial and in a direction such as to lead to unwarranted optimism as to the state of the stock. Such findings call into question several existing predictions regarding MSY of certain types of population, and call for much fuller investigation.

41. Crucial assumptions made in standard stock assessments have not been adequately tested. Modern computing techniques permit some testing of the effects of assumptions, by simulation. Common assumptions are that the natural mortality of exploited organisms is invariant with age, and that the age-dependent pattern of recruitment of young individuals into the exploited stock can be deduced from the age-composition of catches. Recent studies have shown that the recruitment and mortality patterns cannot be separated by analysis of age distributions, and that the assumption of age-invariant mortality is a source of substantial error if it is not valid (11). Many more such studies are needed to evaluate critically the analytical techniques on which present regulatory advice is based.

42. Another common practice in assessments is to apply values for certain population parameters that have been derived from studies of other stocks of the same species, or even of different species. While it seems reasonable to expect a degree of coherence, this practice can lead to management errors. Nevertheless, it seems inevitable that some procedures of this kind will continue to be necessary. Thus, an effort to make them as soundly based as possible will be worthwhile. That calls for more

investigations than hitherto of a comparative nature. Any such transference of parameter estimates from one stock to another, has, at the very least, to be done critically; there are instances in the literature where there has been a veritable chain of transfereces (sometimes even a closed chain) from an initial estimate which was itself erroneous or a guess!

43. Whatever its advantages may be in other respects, a catching regime which tends to stabilize catches and hold population level unchanging can, other things being equal, reduce the availability of the kinds of information that are critical for stock assessment. The dynamic changes in population reveal biological response on which predictions of sustainable yield must be based. A way that has been suggested round this fundamental difficulty is to carry out fishery management as an experiment; that is, to design measures in such a way that their application will enhance the information base. One possibility is to attempt, for example, to hold a stock at a certain level for a period, either by intensifying or by relaxing exploitation, to move it to a substantially different level and observe the changes in mortality rate, growth rate and the like. This is presumably not precluded by the formulations in the Convention, provided it is understood that the ultimate aim is to move the stock to an optimal level. There are, of course, very considerable practical problems. One is the length of time required if such an experiment were to be performed sequentially on a particular stock, and the consequent disruption of industry. Another is the possibility that, between one period and the next, there could be a significant change in environmental conditions. This latter can be avoided if one can reasonably assume that two blocks of a species in different areas are, in other respects than their size, essentially the same. Then experiments can be envisaged in which the two stocks are subject to differing catch regimes simultaneously. Conclusions from such experiments will, of course, be in error to the extent that the assumption is wrong. These two simple examples have been given to illustrate a need for a deeper analysis of some possible experimental designs in fishery management. There are, naturally, other possibilities, but virtually none of them has been seriously explored. The Convention, by making jurisdiction clearer, and therefore encouraging States to take a long-term view of resource use, can provide the conditions in which the experimental approach would be worthwhile and, in the end, profitable.

44. Conservation of living marine resources cannot be achieved only by the determination, under international law, of allowable catches in EEZs and on the high seas and enacting corresponding measures in other zones under national jurisdiction. Other types of measures are envisaged, but not specified, in Arts. 61 and 119. However, such measures are, at least with respect to the EEZ, to be directed to ensuring that "the maintenance of the living resources ... is not endangered by over-exploitation" and, generally, to ensure stock levels that can produce maximum sustainable yields. The emphasis in Parts V and VII of the Convention is almost entirely on the regulation of exploitation. Only in connection with diadromous species and stocks is it envisaged that States will engage in other kinds of activities that will enhance the values of the resources to humans - through measures to renew anadromous stocks, and by ensuring the ingress and egress of migrating catadromous fish. Art. 62 gives an indication of what other measures might be involved in the conservation of

resources in EEZs. An open list is given therein of measures, terms and conditions which may be established in the laws and regulations of the coastal State and with which nationals of other States must comply. These include:

- determining the species that may be caught, and fixing quotas of catch, whether in relation to particular stocks or groups of stocks or catch per vessel over a period of time;
- regulating seasons and areas of fishing, the types, sizes and amount of gear and the types, sizes and number of fishing vessels that may be used;
- fixing the age and size of fish and other species that may be caught.

These are all concerned with the control of exploitation.

45. While such control is always a necessary condition for conservation, and remains the most important one in most fisheries, other human activities connected with other uses of the sea and the coastal zone are yearly increasing their impact on living resources. Among these the possible effects of pollution have received much attention in the past decade or so. This attention is reflected in Part XII of the Convention. There, in Art. 194, States are enjoined to "take all measures ... necessary to prevent, reduce and control pollution of the marine environment from any source ... and to ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment..". Since 'pollution' here means "the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) which results or is likely to result in such deleterious effects as harm to living resources and marine life ..." (Art. 1), Art. 194 gives a firm base for many types of action that will increasingly be needed to ensure the sustainable utilization of the living resources. This, in turn, establishes a requirement for substantial research and marine pollution monitoring to provide scientific bases for such actions. We cannot attempt in this paper even to outline the scientific needs; these are, in any case, being studied intensively by others more competent. It is perhaps in order, however, to offer some observations on this matter. We suggest that a prior need is to investigate the effects of organic biologically active contaminants, particularly on the reproductive processes in a wide range of marine organisms. There is accumulating evidence of the deleterious effects of several of these compounds on the reproduction of the warm-blooded predatory vertebrates - sea-birds and marine mammals. Such effects are not immediately obvious, but the medium- and long-term consequences may be vast. Consequences to the invertebrates and even to fishes are largely unknown. Then there is the question of the introduction of pollution or energy into the environment. Most attention has been given in this connection to thermal energy, but this is generally introduced at the land-sea interface and hence will affect first and mainly, if at all, the resources in internal waters and the territorial sea. The introduction of acoustic energy may be of wider significance. Many of the marine mammals, and possibly other organisms, use a highly developed acoustic sense to explore their immediate environment and to communicate with each other, particularly where the visual sense is impeded by water conditions. It is already clear that some cetaceans are being deleteriously affected by ship noise and other sound generated by human activity. This and related phenomena need investigating further.

46. Another sense used especially by marine organisms, probably particularly by the invertebrates, and about which very little is yet known, is the chemical one. Particular compounds, in extremely low concentrations, play an important role in several biological processes - involving different individuals of a species or individuals of different species - which are necessary for their survival. Such 'communications' may be severely disrupted as a result of the introduction by man of the same, similar or related compounds into the marine environment. This possibility calls for much more attention to certain kinds of pollution than has hitherto been accorded.

47. A third sense which seems to be important to some marine organisms is the electro-magnetic one. Very little is yet known about this, but its recent discovery in birds, and apparently also even in humans, adds credibility to a finding (12, in press) that the stranding of toothed cetaceans is related to patterns of magnetic anomaly. Perhaps in such relations will be found an answer to the puzzle of the method of navigation by highly migratory marine animals such as sperm whales, over deep water, far from land and with limited possibility for visual celestial methods. We are continually astonished by new discoveries and hypotheses about the senses and behaviour of marine animals. Recent examples that come to mind are the stunning of prey by toothed cetaceans, using high intensity sound; and the possibility that migrating tunas may, like vultures, conserve energy by successive vertical displacements and periods of 'gliding'. Critical evaluation of such ideas calls for a degree of collaboration between oceanographers and animal behaviourists we have not yet seen, and may lead not only to dramatic changes in our traditional ideas about marine life, but also to substantial revision of our still very primitive view of the problems of marine resource use and conservation.

48. Another form of 'introduction by man into the marine environment' is that of alien species. These are referred to in Art. 196 of the Convention, which requires that States 'take all measures necessary to prevent, reduce and control ... the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto'. Both kinds of introductions have, of course, been made in the past, and we have much to learn from study of the events that they set in train. The change in fauna of the Mediterranean Sea as a result of movement of Indo-Pacific species through the Suez canal is fairly well documented, and there has been much discussion of the possible consequences of the construction of a sea-level canal connecting the Pacific with the Caribbean. In recent decades, several deliberate introductions have been contemplated, for economic ends. The idea of introducing salmon into the Southeast Pacific - Southern Ocean has already been mentioned, and Soviet scientists have proposed the introduction of the northern herring into the southern hemisphere. One attitude to deliberate introductions is that "they should obviously be avoided as much as possible since it is often impossible to determine in advance if they may have significant and harmful effects." (Ref. 5, which also gives several examples of past introductions and their consequences.) We would go further and observe that it is always impossible to make such determinations. Nevertheless, with appropriate biological and environmental studies in advance some judgements could probably be made of the probabilities of certain kinds of consequences with respect to different types of organisms. Certainly, since any effects are likely, eventually, to be widespread, extending beyond the jurisdictions of nations intending to make introductions or to undertake works that could lead to

accidental introductions, a notification and advance assessment procedure, with international involvement, is highly desirable. This would call for substantial research programmes. Meanwhile, it is imperative that we learn as much as possible about the consequences of all past introductions.

49. We have referred to engineering works, such as canal building, which can lead to faunistic and floristic changes. Other major works, while perhaps unlikely to lead to the addition of new species, can change markedly the species composition in relative terms, and the distributions of naturally occurring species. Construction of river and tidal barrages is one of these. For example, the changes in the flow of the Nile, associated with the Aswan high dam, have apparently affected the distribution and abundance of commercial fish species along the coast of the Eastern Mediterranean. The Convention is remarkably silent about such matters, yet we must in the future expect to experience more consequences from human activities in coastal zones - and even far inland - as well as from activities in the marine environment itself. Perhaps Art. 194, para. 5, can help in the evolution of international co-operation and harmony in such matters. It provides that the "measures taken in accordance with this Part (which is entitled 'Protection and Preservation of the Marine Environment', although the article defines measures to prevent, reduce and control pollution) shall include those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life". Although a strict interpretation of this could be that it applies only to measures against pollution, as defined in Art. 1, consideration of Art. 192 - which identifies a more general obligation, to protect and preserve the marine environment - would perhaps permit a wider interpretation. In any case, it is evident that scientific information of many kinds would be needed in advance of any activities that could substantially affect the living resources, that long-term monitoring and continued research would be necessary after any such changes have been made, and that substantial international co-operation in these would be called for.

50. Another influence of human activities on living resources to which no attention is given explicitly in the Convention is the accidental and incidental take of non-target species in fishing operations. This is already a problem of great importance with respect to some species; incidental catches of several species of dolphins in tuna fisheries - which have led to severe depletion of the mammals in some cases - are well-known, as is the world-wide accidental capture of turtles in fishing gear. Very large quantities of fishes, including the young of commercially important species and others that are at present considered worthless in the circumstances of capture, but are of potential value in different circumstances, are taken in prawn fisheries. Ocean drift nets are now killing very large numbers of cetaceans, pinnipeds, sea birds and unwanted fishes. The world-wide use of strong, non-biodegradable synthetic fibres in fishing nets means that even large animals cannot break out from them. Lost and discarded nets drift about the ocean in ever increasing thousands, for many years, killing fishes and other animals indiscriminately \*.

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\* This appears to fall within the definition of 'marine pollution', in the Convention, - by materials. Other such pollution is by plastic and rubber membranes and lines, which are known to choke seals and impede fish.

The effects of such incidental take are largely unknown. It seems certain that this sort of thing will become more frequent; it is not possible to be more explicit, because the present types and levels of incidental take are not known. IUCN announced some years ago the launching of a project to assemble information and evaluate it, as well as to design programmes of research to assess the major effects and to eliminate or, at least, reduce the causes. This project has not been implemented (apparently because FAO, with which IUCN wished to collaborate, was not enthusiastic), but in our judgement the need remains, and its satisfaction is in fact increasingly urgent. While we understand that the references in Arts. 61, 63 and 119 to consideration for 'associated species' were inserted in the text with other phenomena in mind, they could perhaps provide some basis in international law for consideration of the consequences of incidental catches. The notion of biological association would certainly apply to the dolphins and tunas taken together in tuna purse-seines, and other species, such as fish and turtles taken with target species in the same fishing gear might be considered as technologically associated with the target species. (Ref.5, pp 75-76, 172 and 407 gives a short review of this matter and some suggestions for institutional action to resolve it.) In the case of incidentally taken species that may be depleted, threatened or endangered, or may become so thereby (which case might also be covered by Art. 194, para. 5), the need is clearly to reduce or eliminate the incidental catch as soon as possible by appropriate changes in fishing technology or operations. As work on dolphins has shown, this calls for research on the behaviour of the threatened animals, as well as on their population dynamics. In other cases, where the incidentally taken species may be affected but not threatened, complete elimination of such take would not usually be called for. Nevertheless, some regulation of it will surely be necessary and, for such regulation to have the intended results, it would need to be based on substantial knowledge of the patterns and scale of the occurrences of incidental takes, and of the dynamics of the systems containing these species and the target species.

## CONCLUSIONS

51. As pieces of coherent and meaningful drafting, the sections of the new Convention on the Law of the Sea dealing with living marine resources have little to commend them. Less care seems to have been given to their composition than to other sections of the Convention. Perhaps more importantly, there is little evidence of awareness of the implications of scientific research concerning the assessment and sustainable use of living resources that was going on and being publicly debated in international organizations during the drafting of the Convention. Nevertheless, the text will surely be used as a guide, to justify actions, to be quoted in disputes and to suggest questions about the rational management of resource utilization.

52. The Convention can be a rich source of questions for marine scientists to ponder and to which to seek answers. This could disturb the apparent complacency of many practitioners in the 'actuarial school' of fish-stock assessment, and that will be to the general good. If, in attempts to apply provisions of the Convention, some of their assumptions are given more than the usual scrutiny, that will be to the good of applied marine science and of its reputation. More positively, implementation of those sections of the Convention that we have been reviewing will call for a very much broader view of what in marine science is directly relevant to practice and, we hope, a corresponding expansion and integration of that

science. This will be primarily the collective responsibility of the scientists themselves. They can benefit, as always in this field, by nurturing understanding with lawyers and administrators (those in government and those in industry), and especially by working closely, as they have traditionally done, with fishermen and other seamen. But, for success at this particular time in maritime history, they need the backing of governments and the support of the international organizations to which the governments belong.

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