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# APPENDIX

## Catch and Potential of Major Fisheries Resource Systems in Tropical and Subtropical Areas[a]



[a] Compiled by Villy Christensen, Abbie Trinidad-Cruz, James Paw, Jun Torres, and Daniel Pauly, ICLARM, Manila, April 1991. Revised January 1992.

## I. Introduction

The need for fish for food is increasing rapidly in the developing parts of the world. Over the past decades the catches have managed to approximately balance the population increase (Fig. 1), but whether this can continue is far from certain. The present status of the fisheries indicates that in major parts of the developing world, high population densities have already led to overfishing. Further, the potential for increased catches *with the present management strategies* lies mainly in offshore fisheries and in fisheries off less populated areas. The potential from non-traditional fisheries is very limited in the more populated areas, where the stocks are already heavily exploited. To expand the catches in these areas new strategies must be introduced.

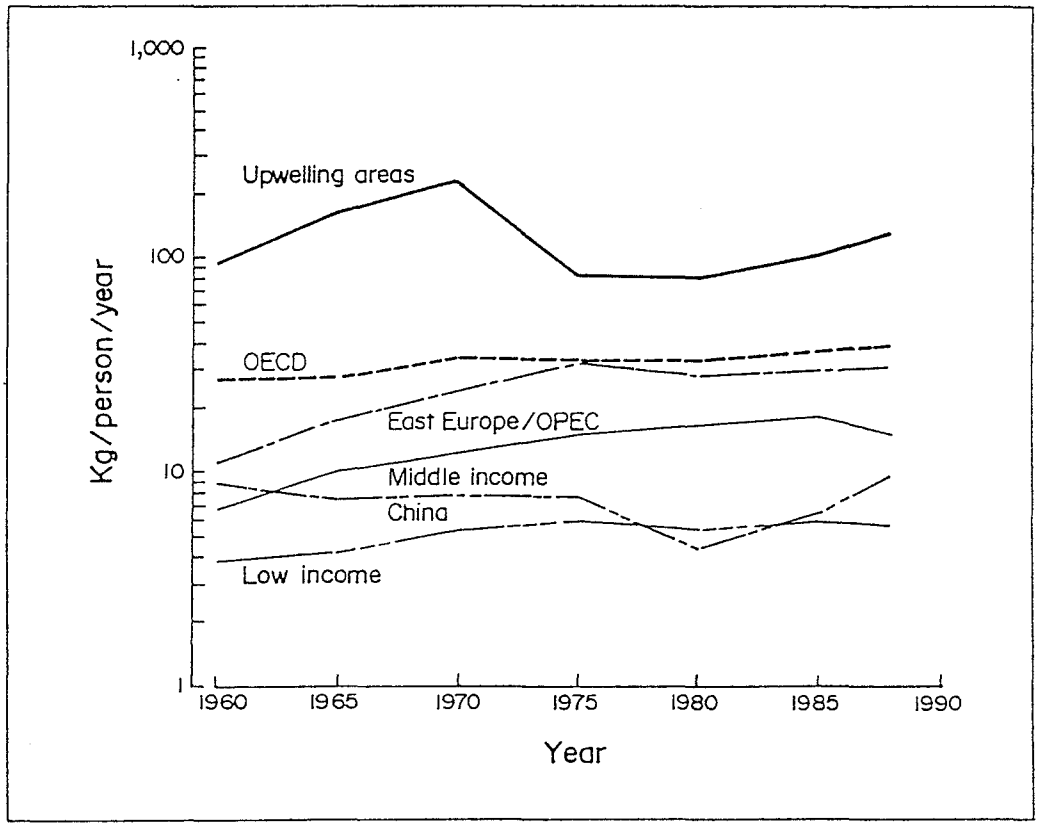


Fig. 1. Per caput fish production by country groupings over the period 1960-1988. The countries with major upwelling areas include Peru, Chile, Morocco, Mauretania, Sénégal, Angola and Namibia.

The guidelines for how to proceed are clear: ways must be found to reduce the fishing pressure and to protect the juvenile fish. This is simple advice but unfortunately of a kind that one cannot expect, under present circumstances, to see successfully implemented anywhere. The major reason for this has been lack of understanding of the sociological and biological implications of the proposed measures. This situation can

only be improved through research on how fish and fisher populations interact and how fishers plan and conduct their activities.

The potential for increasing the fish production differs between resource systems. This will be described further in Section V.

The present account was compiled in an attempt to evaluate, in terms of production and potential, the relative importance of the major aquatic resource systems of special interest for international fisheries research. The resource systems are described further in Section III.

## II. Methodology

The term 'fish' as we use it here includes, in addition to finfish, aquatic invertebrates and a small number of reptiles. Seaweeds (annual production about 1.6 million tonnes in 1988) are not included; they are treated as aquaculture produce. Marine mammals are also excluded. The terms demersal(s) and pelagic(s) are used to represent types of finfish which occur at or near the sea floor and in the midwater or upper layers of the sea, respectively. This usage follows FAO and excludes invertebrates such as crustaceans (e.g., shrimp) and molluscs (e.g., mussels, squid).

The information used for this compilation mainly comes from FAO catch statistics complemented by data specific to various resource systems. The FAO statistics are based on geographical regions and as such are difficult to use in a resource system context. This will invariably lead to error in the results; we have reason to hope, however, that these errors will not severely influence the general conclusions.

Estimates of catch potential or maximum sustainable yield (MSY) can be obtained in several ways. Two often-used methods are *1)* for lightly exploited systems to assume the MSY to equal half the virgin biomass times the natural mortality of the population (Gulland 1971); and *2)* for heavily exploited systems to plot time series of yield *versus* fishing effort and, from the scatter plot, estimate the MSY.

A major drawback of the latter method is that the effort data, especially for small-scale fisheries, are of a very poor quality. Further, this method is based on the existing fishing pattern. Most or all of the intensive fisheries in developing countries are characterized by application of excess effort and by use of fine meshed gear. Changing the fishing pattern by, e.g., introduction of sanctuaries, larger mesh sizes and increased use of passive gears instead of trawls, have in many cases led to catches higher than would have been the MSY, as estimated using yield *vs* effort plots.

The present analysis describes aspects of fisheries in developing areas of the world. As the FAO summary statistics are based on FAO geographical regions we have where needed used the regions in Table 1 as representative for the developing countries. This is an approximation, and the results will only be comparable to, not identical with, results from analysis explicitly incorporating developing countries only.

Table 1. FAO areas included in tabulations of tropical and subtropical areas.

| FAO Region | Area |
|---|---|
| 1 | Africa |
| 4 | Asia |
| 23 | South America |
| 31 | Atlantic, WC |
| 34 | Atlantic, EC |
| 41 | Atlantic, SW |
| 47 | Atlantic, SE |
| 51 | Indian Ocean, W |
| 57 | Indian Ocean, E |
| 71 | Pacific Ocean, WC |
| 77 | Pacific Ocean, EC |
| 87 | Pacific Ocean, SE |
| | Mexico |
| | China |

## III. The Resource Systems

The resource systems considered here are

a) Uplands
b) Ponds, including small water bodies
c) Reservoirs and lakes
d) Rivers, floodplains and swamps
e) Estuaries and lagoons
f) Coral reefs
g) Shelves with soft bottom
h) Shelves with upwelling
i) Open oceans

The resource systems are defined as follows:

a) Uplands: Terrain with steep gradients at the higher elevations of catchments, where little or no fishery or aquaculture is possible.

b) Ponds: Ponds are small freshwater bodies, usually artificial, occasionally natural, in rainfed and irrigated areas where aquaculture, particularly integrated with agriculture is possible. Flooded rice fields are hence considered as ponds. Ponds are normally characterized as being under private individual or group ownerships or leasing arrangements.

c) Reservoirs and lakes: Reservoirs are natural or artificial waterbodies, primarily used for irrigation, hydroelectric power and domestic water supply. Lakes are natural waterbodies. Both are usually freshwater and have high potential for aquaculture and conventional or enhanced capture fisheries. They are usually considered common property and there may be free access to fishing or aquaculture sites.

However, in some cases, rights are leased from the government or from other authorities, groups or individuals.

d) Streams, rivers and floodplains: Streams and rivers are flowing waters while floodplains are the lowland areas, adjacent to watercourses that are subject to periodic or near-permanent inundation and sediment deposition. Streams, rivers and floodplains support substantial inland fisheries and have potential for enhanced fisheries. Normally all these systems are common property and have open access, except where access and/or ownership, attached to surrounding lands, restricts this.

e) Estuaries and lagoons: Estuaries are semi-enclosed coastal waterbodies with free connection to the open sea and within which seawater is diluted with freshwater from land drainage (e.g., brackishwater). Lagoons are shallow waterbodies resembling ponds or lakes, which usually have one or more shallow restricted outlets to the sea. This grouping includes the key habitats, such as mangrove, that support coastal fisheries. It also has potential for aquaculture and for enhanced fisheries. Coastal waters out to 10 meters depth are included here to encompass most of fishing grounds by small-scale fishers. These areas are usually directly adjacent to soft-bottom shelves (see below), leading to conflicts with the (trawl) fisheries operating there. Brackishwater ponds are included in this system. They are either natural or man-made; often the result of conversion of mangrove swamps. This resource system is often an area of intense intersectoral conflict over competing uses.

f) Coral reefs: Areas of continental and island shelves in tropical oceans in which reef-building corals are dominant features, forming scattered patch reefs, fringing reefs or barrier reefs and usually large areas of shallow coraline enclosed waters. The latter have potential for aquaculture. This is often an area of intensive fishing and gleaning. There may be traditional use rights but reefs are often considered open access.

g) Soft-bottom shelves: These are the relatively shallow (up to 10-200 m deep) productive areas surrounding continents. In the tropics, it is mainly the upper, nearshore parts (10-50 m) of the shelves which sustain marine fisheries. There are strong interactions (and conflicts) between nearshore small-scale fisheries and large-scale commercial operations.

h) Upwelling shelves: Upwelling is the process in which cold, nutrient-rich water is brought to the surface of the sea from deeper layers. This process mainly occurs on the eastern side of oceans, driven by the interaction of strong and steady winds directed towards the equator and the earth's rotation. The upwelled water fertilizes the sea, enabling the support of large populations of a few species of small (anchovies and sardines) and large (bonitos, mackerels) pelagic fishes. These areas also support large populations of sea birds and sea mammals. In addition to the four major upwelling areas (off Peru, California, North West Africa and Angola/Namibia), scattered smaller upwellings occur throughout the tropics, e.g., in the Arabian Sea and in Indonesia. In most cases, upwellings are fished by medium- to large-scale industrial fishing vessels.

i) Open oceans: The open seas beyond 200 m depth, where mainly oceanic resources such as tuna and large squid are fished by commercial or large-scale enterprises.

## IV. Occurrence of Fish Groups in Resource Systems

Fisheries commodities are defined using the format used by FAO. FAO provides annual catch data for 950 individual species or group of species, regrouped in 51 clusters. The groupings are based on the FAO 'International Standard Statistical Classification of Aquatic Animals and Plants' or ISSCAAP (FAO 1990).

For the present analysis we have grouped the data into 26 commodity groups and indicated in which of the considered resource systems the major catches are taken (Table 2). The commodity groups consist of clusters of related species.

The main conclusion that can be drawn from Table 2 is that the importance of the different commodities varies between resource systems.

The importance of the commodities also shows regional differences. Fearn and Davies (1991) presented a comprehensive analysis of potential regional benefits from fisheries commodity research for the major commodities. They defined regional benefits as direct and spillover benefits to all countries in the

Table 2. Distribution of catches (million tonnes per year) in tropical and subtropical areas by ISSCAAP groups. Stars indicate where major parts of catches occur in the resource systems. Aquaculture production is not included.

| ISSCAAP Code | Group of species | Total[a] catch | Up-lands | Ponds | Lakes, reserv. | Floodpl. rivers | Est. lag. bays | Coral reefs | Shelves A | Shelves B | High seas |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | Carps and other cyprinids | 0.59 | | * | * | * | | | | | |
| 12 | Tilapias and other cyprinids | 0.31 | | * | * | * | | | | | |
| 13 | Misc. freshwater fishes | 4.01 | * | * | * | * | | | | | |
| 41 | Freshwater crustaceans | 0.18 | | * | * | * | | | | | |
| 2 | Diadromous fishes | 1.11 | | | * | * | * | | | | |
| 51 | Freshwater molluscs | 0.26 | | | * | * | | | | | |
| 31 | Flatfish | 0.10 | | | | | * | | * | | |
| 33 | Bashes, congers, etc. | 2.49 | | | | | * | * | * | | |
| 34 | Jacks, mullets, etc. | 6.14 | | | | | * | * | * | | |
| 38 | Sharks, rays, etc. | 0.42 | | | | | | | * | | |
| 42 | Crabs, etc. | 0.65 | | | | | * | | | | |
| 43-44 | Lobsters, etc. | 0.09 | | | | | * | * | * | | |
| 45 | Shrimps, prawns, etc. | 0.99 | | | | | * | | * | | |
| 47 | Other marine crustaceans | 0.07 | | | | | * | * | * | | |
| 52 | Abalones, winkles, etc. | 0.05 | | | | | * | | * | | |
| 53-54 | Oysters and mussels | 0.10 | | | | | * | | * | | |
| 55 | Scallops | 0.04 | | | | | * | | * | | |
| 56 | Clams, cockles, etc. | 0.20 | | | | | * | * | * | | |
| 57 | Squids, cuttlefishes, etch. | 1.30 | | | | | * | | * | | |
| 58 | Misc. marine molluscs | 0.16 | | | | | * | * | * | | |
| 7 | Misc. invertebrates | 0.19 | | | | | * | * | * | | |
| 32 | Gadoids | 1.73 | | | | | * | | * | * | |
| 35 | Sardines, anchovies, etc. | 13.07 | | | | | * | | * | * | |
| 36 | Tunas, bonitos, etc. | 2.25 | | | | | | | * | * | * |
| 37 | Mackerels, etc. | 2.12 | | | | | * | | * | * | * |
| 39 | Misc. marine fishes | 6.09 | | | | | * | * | * | * | * |
| Total | | 44.69 | - | - | 1.8 | 3.5 | 5.1 | 6.0 | 11.1 | 14.0 | 3.1 |

[a] FAO Statistics, 1988 for FAO geographic areas 1, 3, 4, 31, 34, 41, 47, 51, 57, 71, 77, 87 and China.

geographic region where the research is being undertaken and found the dominant financial benefits to come from prawns and shrimps in South East Asia, from clams in South Asia, carps in China, tuna in the South Pacific, small pelagics in West and North Africa, and miscellaneous diadromous fish (fish which migrate from the sea to freshwater or *vice versa*) in other parts of Africa (Table 3).

Table 3. Potential regional benefits from fishery commodity research. (Source: Fearn and Davis 1991)

| South East Asia | | South Asia | | China | |
|---|---|---|---|---|---|
| Commodity | Regional benefits (SUS x $10^6$) | Commodity ranking | Regional benefits (SUS x $10^6$) | Commodity ranking | Regional benefits (SUS x $10^6$) |
| Prawns/shrimps | 21.9 | Clams | 61.3 | Carps | 335.1 |
| Demersal/pelagics | 12.0 | Misc. diadromous | 40.6 | Prawns/shrimps | 28.9 |
| Herrings & others | 6.6 | Prawns/shrimps | 25.9 | Demersal/pelagics | 7.3 |
| Tilapia | 2.7 | Carps | 23.8 | Mussels | 5.2 |
| Lobsters | 0.8 | Demersal/pelagics | 23.0 | Mackerels & others | 4.3 |
| Mackerels & others | 0.8 | Tilapia | 9.4 | Tuna & others | 2.5 |
| Tuna & others | 0.5 | Oysters | 6.1 | Herrings & others | 0.2 |
| Carps | 0.1 | Mussels | 4.9 | Oysters | 0.0 |
| Misc. diadromous | 0.1 | Tuna & others | 3.7 | Tilapia | 0.0 |
| Clams | 0.0 | Herrings & others | 3.6 | Misc. diadromous | 0.0 |
| Oysters | 0.0 | Lobsters | 3.5 | Lobsters | 0.0 |
| Mussels | 0.0 | Mackerels & others | 3.5 | Clams | 0.0 |

| South Pacific and Papua New Guinea | | Africa | | West Asia North Africa | |
|---|---|---|---|---|---|
| Commodity ranking | Regional benefits (SUS x $10^6$) | Commodity ranking | Regional benefits (SUS x $10^6$) | Commodity ranking | Regional benefits (SUS x $10^6$) |
| Tuna & others | 4.4 | Misc. diadromous | 20.6 | Herrings & others | 9.5 |
| Demersal/pelagics | 0.5 | Carps | 8.1 | Carps | 2.8 |
| Lobsters | 0.2 | Lobsters | 4.8 | Demersal/pelagics | 1.6 |
| Prawns/shrimps | 0.1 | Tilapia | 4.1 | Mackerels & others | 1.2 |
| Clams | 0.1 | Herrings & others | 1.4 | Prawns/shrimps | 0.6 |
| Misc. diadromous | 0.1 | Demersal/pelagics | 1.0 | Lobsters | 0.6 |
| Tilapia | 0.1 | Oysters | 0.3 | Tuna & others | 0.3 |
| Carps | 0.0 | Tuna & others | 0.2 | Mussels | 0.1 |
| Oysters | 0.0 | Prawns/shrimps | 0.2 | Oysters | 0.0 |
| Herrings & others | 0.0 | Mackerels & others | 0.1 | Misc. diadromous | 0.0 |
| Mackerels & others | 0.0 | Clams | 0.0 | Tilapia | 0.0 |
| Mussels | 0.0 | Mussels | 0.0 | Clams | 0.0 |

## V. Catch and Potentials by Resource Systems

### a) Uplands

Very little fishing takes places in this resource system and the system offers very little potential. We have for these reasons opted to discuss neither status nor potential for the uplands.

### b) Ponds

In ponds only negligible catches are taken, and the area does not offer any noteworthy potential for increases of the capture fisheries. Research effort in these areas should concentrate on aquaculture production.

(c) Reservoirs and Lakes

Lakes are to a large extent a temperate phenomenon. In the tropics and subtropics, only Africa has large natural lakes. The three largest (Victoria, Malawi and Tanganyika) cover a combined area of 134,000 km². Only few large natural lakes are found in the tropics outside Africa. Indonesia has three that can be considered large - Lakes Toba (Sumatra), Towuti and Poso (Sulawesi). Very few natural lakes are found in South and Central America.

Artificial lakes, i.e., reservoirs comprise the greatest areas of stable standing waters in the tropics. In the 56 countries and associated islands of Africa, there are 320 major dams and reservoirs occupying a total of 41,000 km² (total maximum surface area).

Reservoir fisheries in Africa contribute roughly 10% or 150,000 tonnes annually to inland fisheries yield. Yet, the full biological and economic potential of reservoir fisheries has rarely been realized. This is primarily because reservoirs were established for purposes other than fisheries; little is known about how to manage reservoir fisheries.

In Asia, reservoir fisheries play a significant role in India and in Sri Lanka. The latter has the highest relative proportion of small reservoirs in the world.

The distinction between lakes and reservoirs may seem academic - after all a reservoir is a lake that was just more recently dry land or a river. However, due to the brief history of the reservoirs they do not possess the variety of life forms that characterizes a lake. This raises a need for careful consideration as all ecological niches may not be filled, something that often results in inefficient transfer from primary production to fish yield. As an example, introduction of sardines to the artificial Lake Kariba resulted in a niche being filled and in sustainable catches of over 20,000 tonnes annually. This indicates that management based on understanding of ecological interactions raises potential for enhancing the fish productivity.

The productivity of tropical lakes is related to their topography. Shallow lakes generally have a higher productivity than deeper ones. This is related to a higher shallow water primary production and to generally shorter food webs in shallow areas. Reservoirs, usually being more dendritic and thus with longer shorelines than lakes, have a potentially higher productivity than lakes - once their various niches are occupied. Fig. 2 shows the relationship between fish yield and primary productivity for tropical lakes and reservoirs.

Small lakes tend to be fully exploited, while larger lakes often are less utilized in the offshore areas. The relationship between fish catches and effort for a number of African lakes is given in Fig. 3. As this figure includes yields (not maximum sustainable yields) from a number of lakes, it can only be concluded that the yields of African lakes do not increase when there are more than two fishers per square kilometer.

Total catches from lakes and reservoirs are difficult to estimate from the statistics where they are grouped with production from river systems and from freshwater aquaculture. Total freshwater production in the developing world was some 10.8 million tonnes in 1988. Of these, 5.5 million tonnes can be attributed to aquaculture (mainly in ponds), leaving 5.3 million tonnes for capture fisheries. The breakdown of the catches between the two main freshwater resource systems is uncertain. We only know of qualitative

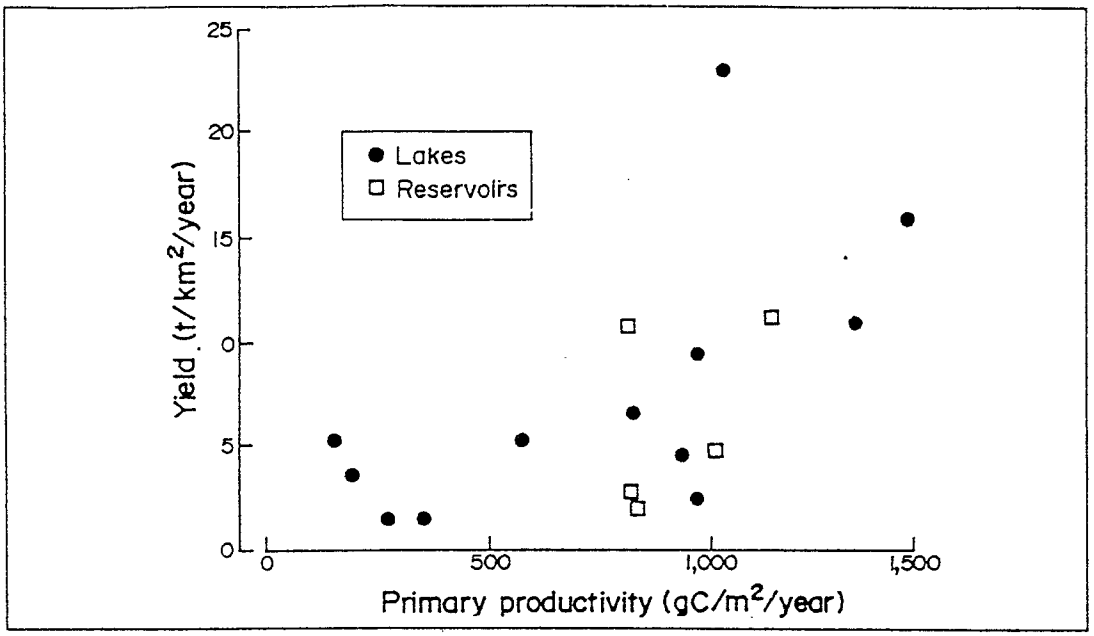


Fig. 2. Fish yields and primary productivity in tropical lakes and reservoirs. (Source: Marten and Polovina 1982)

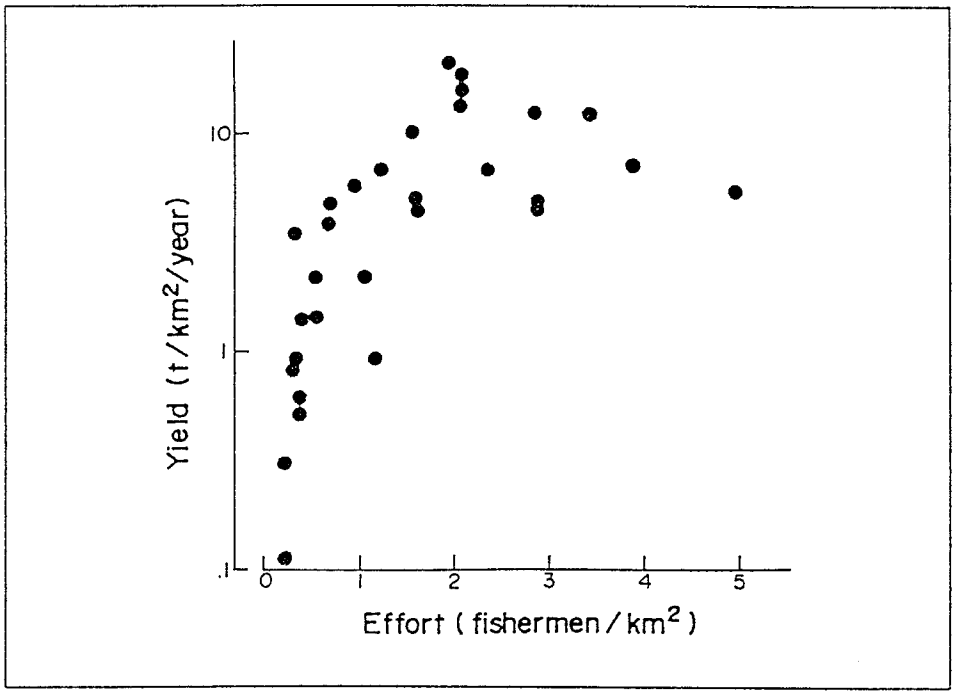


Fig. 3. Fish yields and fishing effort on African lakes. (Source: Henderson and Welcomme 1974)

evidence suggesting that most catches are taken in floodplains, rivers and swamps. We have therefore allocated 1/3 of the catches to lakes and reservoirs, and 2/3 to floodplains, rivers and swamps. This results in an estimate of annual catch in lakes and reservoirs of 1.8 million tonnes.

(d) Floodplains, rivers and swamps

The bulk of the world's freshwater fish catch is taken from running waters and their seasonal flood zones - fringing floodplains (lateral flood zones), internal deltas and coastal deltas. Of these, the coastal deltas of rivers are subsumed under "estuaries and lagoons" and are discussed further below.

The mean catch rates for tropical rivers and floodplains in Africa, Central and South America, and Asia have been estimated at 5.2 tonnes $km^{-2}$ $year^{-1}$ (Wellcome 1985). It was not possible, due to the considerable variations in the catch rates, to identify any differences between the three continents.

The catch rates from rivers vary more than for lakes. Low productivity occurs in headwaters in areas of highly weathered soils where the primary productivity is low. Contrarily, high productivity can often be attributed to input of nutrients and organic material from watershed areas including sewage from cities. Further, a good part of the fish catches in rivers comes from fish passing through on feeding or breeding migrations. This leads to catches in excess of what can be supported by primary production.

Total catches from all rivers, floodplains and swamps are not known. As explained in the section above a first, crude estimate of total production in the resource system is 3.5 million tonnes annually. The potential for considerable increases in the catches seems limited.

The total production of tropical rivers and floodplains amounts to some 4% of global fish production. As such it may seem unimportant, but as the rivers and floodplains are harvested almost exclusively by small-scale fishers for local consumption, it constitutes an important food source in otherwise impoverished areas. It also should be noted that the statistics for this type of small-scale fishery rarely receive much attention from the responsible authorities. Therefore, the actual catches may be underestimated.

When the number of fishers in a river system increases, the catches per unit area decrease. This is illustrated in Fig. 4 where a regression between catch per unit effort (CPUE) and effort shows a clear negative correlation (Wellcome 1985). The trends are the same in Fig. 5, where a time series of catch/effort data from the Nile downstream of the Aswan Dam is summarized (Wellcome 1985). Here, the development from an under- to an over-exploited fishery is clearly demonstrated. Over a ten-year period, the area yielded a more or less constant catch of 8,000 tonnes per year despite a threefold increase in effort.

Data on fisherfolk populations and effort are often difficult to obtain. This sort of information is, however, badly needed to develop realistic management models.

(e) Estuaries and lagoons

This resource system covers non-reef coastal areas and includes coastal deltas, estuaries and other nearshore areas down to approximately 10 meters depth. The depth limit is set mainly to include most of the catches by coastal small-scale fisherfolks in the category.

The total area of this resource system is difficult to estimate, as a detailed database is not available. From information in Gulland (1971) the total shelf area (0-200 m depth) can be estimated at 10.9 million $km^2$ for developing countries. Of these 0.7 million $km^2$ are attributed to upwelling areas. One-quarter of the total area is assumed to be within 0-50 meters deep, where the vast majority of the catches are taken. This

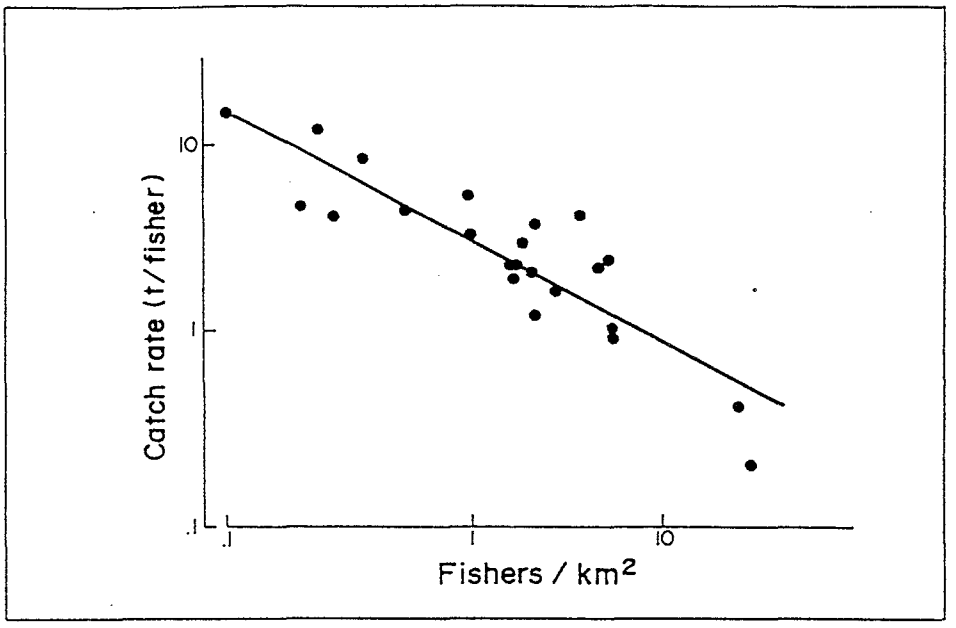


Fig. 4 Catch per unit effort as a function of effort for 17 rivers; CPUE = 2.92 * (Fisheries/km²)$^{-0.4}$. (Source: Welcomme 1985).

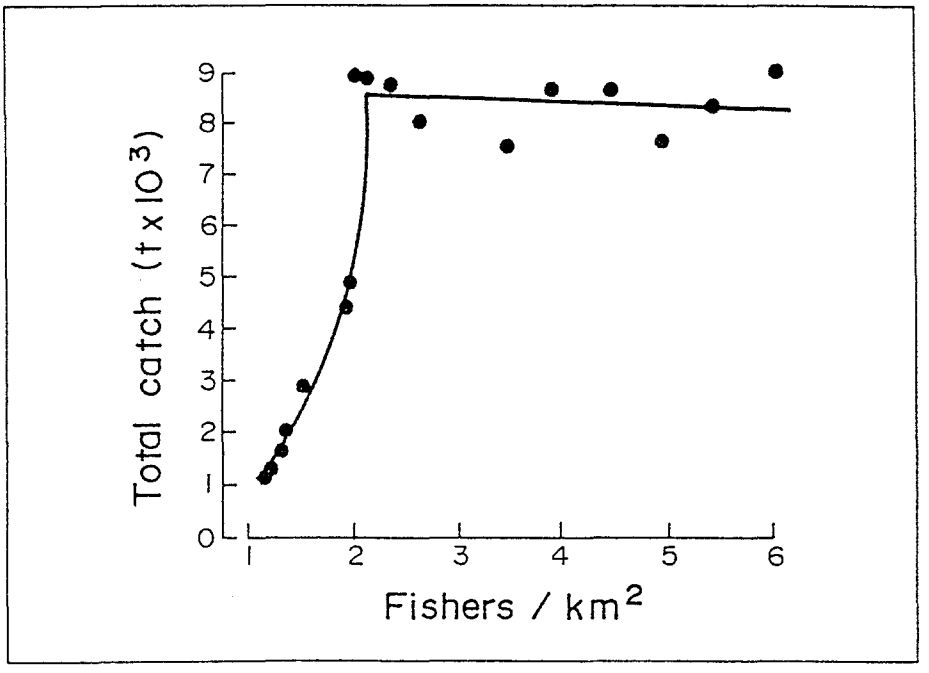


Fig. 5. Plot of total catch against the number of fishers for the Nile south of the Aswan Dam. (Source: Welcomme 1985).

corresponds to 2.7 million km², of which 0.6 can be attributed to coral reefs (see below). The remainder is assumed to be distributed between estuaries and lagoons, and softbottom shelves in proportion to the estimated catches in the systems, i.e., as 5.1 to 11.1. This corresponds to 0.7 and 1.5 million km² respectively.

Overall, it is a heterogeneous area, characterized by *(i)* high productivity, attributable to mangrove litterfall and substantial import of nutrients from river runoff; and *(ii)* being an important nursery area for fish and penaeid shrimp. The systems are exploited mainly by small-scale fishers. In recent years, this use has led to conflicts with expanding coastal aquaculture operations. Governments tend to support export-oriented, capital-intensive shrimp culture, often at the expense of small-scale fishing opportunities.

Total catches from the resource system are difficult to estimate. We have used an indirect estimation procedure. The proportions of the catches taken by small-scale and large-scale fisheries in the considered region are estimated to be approximately the same (Thompson 1980; Pauly and Christensen *in press*). Using a 1:1 ratio we estimate the total production for the coastal water resource systems to be 11.1 million tonnes per year. The catches from coraline areas amount to some 6 million tonnes annually (Smith 1978). Therefore, the catches from estuaries, bays and lagoons can be approximated to 5.1 million tonnes annually.

The fisheries in the tropical coastal areas are characterized by growth overfishing throughout. The high fishing pressure forces fishers to use mesh sizes far below the optimal. The fisheries, therefore, become highly opportunistic and dependent on seasonal pulses of new recruits.

(f) Coral reefs

Smith (1978) attempted to estimate the proportion of the ocean surface area that can be attributed to coral reefs. His estimates lead to an estimate of 617,000 $km^2$ of coral reefs for the entire world.

Based on work done in Jamaica by J.L. Munro, Smith (1978) assumed a fisheries yield of 8 tonnes $km^{-2}$ $year^{-1}$ for coral reefs and adjacent reef areas; this led to an estimated annual yield (potential or realized) of 6 million tonnes annually for the entire coral reef regions of the world.

However, yield per coral reef surface area appears to be extremely variable both for natural reasons and due to different levels of exploitation or reef degradation. A high figure of 32 tonnes $km^{-2}$ $year^{-1}$ is obtained from a well managed Philippine reef, of which the catch sold was 11.3 tonnes, catch consumed 10.7 tonnes and local drying 11.7 tonnes (White and Savina 1987). The above figure of 8 tonnes, which may be a reasonable estimate of the "mean yield", could well be increased given improved management or decreased, if overfishing and coral reef destruction continue unabated.

The potential fish yield from coraline areas is high, perhaps much higher than until now assumed. Fig. 6 shows the relationship between yield from coral reefs and fishing effort. The figure does not show any levelling off due to increased effort; reefs seem to be able to sustain considerable fishing pressure if administered wisely. Noteworthy also are some community-based management initiatives from several intensively fished Philippine reefs, as mentioned above, where increases in catches by a factor of 2 to 3 have been experienced mainly through abolishing destructive fishing and introducing community-based enforcement of fish sanctuaries, (Fig. 7).

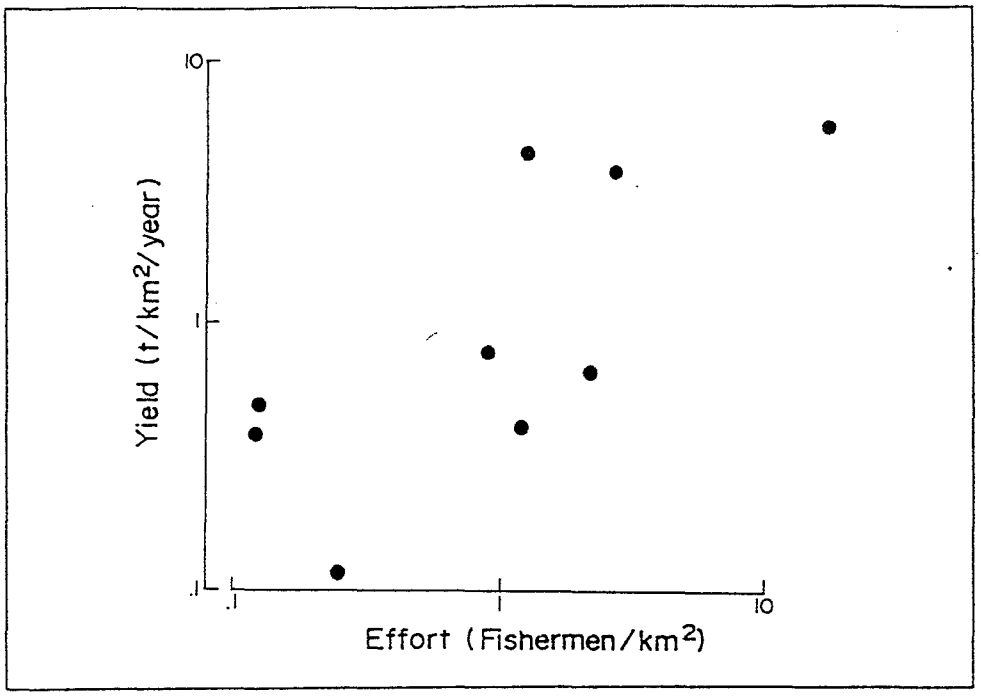


Fig. 6. Fish yields *vs* fishing effort in coral reefs. (Source: Marten and Polovina 1982)

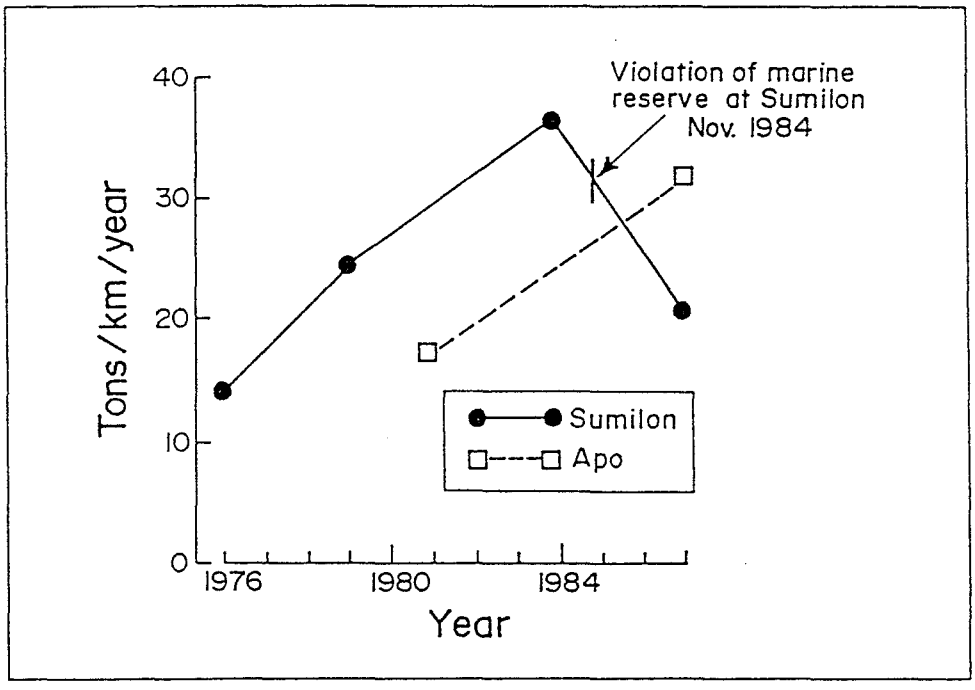


Fig. 7. Change in fish yield reported for Sumilon and Apo Islands, reflecting the effects of different management schemes. (Source: White and Savina 1987)

(g) Shelves with soft bottom

The total area of soft-bottom shelves (10-50 m depth) was estimated above to be some 1.5 million km². The potential maximum sustainable yield (MSY) of tropical demersal and pelagic marine fisheries varies considerably. The ranges in MSY for tropical continental shelf areas in different geographical regions are given in Table 4, where similar ranges for upwelling areas are included for comparison.

Table 4. Estimated maximum sustainable yields (t/km²/year) for tropical continental shelf areas. (Source: Marten and Polovina 1982)

| | Minimum | | | Maximum | | |
|---|---|---|---|---|---|---|
| Region | Pelagic | Demersal | Total | Pelagic | Demersal | Total |
| NE Atlantic | 0.8 | 0.6 | 1.4 | 7.3 | 8.0 | 15.3 |
| NW Atlantic | 1.8 | 1.8 | 3.6 | 7.0 | 7.0 | 14.0 |
| NW Pacific | 0.6 | 1.7 | 2.3 | 8.5 | 4.0 | 12.5 |
| Indian Ocean | 0.7 | 1.4 | 2.1 | 4.3 | 5.5 | 9.8 |
| E Central Atlantic | 4.0 | 1.2 | 5.2 | 5.0 | 2.5 | 7.5 |
| South China Sea | 0.2 | 0.8 | 1.0 | 2.4 | 4.3 | 6.7 |
| W Central Atlantic | 0.7 | 0.2 | 0.9 | 3.2 | 2.5 | 5.7 |
| | | Upwelling | | | | |
| SW Atlantic | 1.5 | 6.0 | 7.5 | 17.5 | 10.0 | 27.5 |
| Peru | - | - | - | 1.0 | 21.9 | 22.9 |

The MSY of the continental shelf demersal fisheries is strongly negatively correlated with the mean depth on the shelf (Fig. 8). On the other hand, the MSY shows a clear relationship with primary productivity, as illustrated in Fig. 9 for tropical pelagic fisheries.

Total catches from the soft-bottom shelf areas of developing countries are difficult to estimate directly due to lack of suitably compiled data. Indirectly the catches can be estimated by first taking the difference between the total fish catches in the regions considered (Table 1), and the catches in freshwater, in upwelling areas and in the open oceans. This difference gives the total catches in coastal and soft-bottom shelf areas, which are split between the systems in a 1:1 ratio, as discussed earlier. The results from these manipulations are shown in Table 5, where total catches for the soft-bottom shelf areas are estimated at some 11.1 million tonnes for 1988. The catches from soft-bottom shelf areas are thus approximately as large as (and much more valuable than) those from upwelling fisheries.

A few decades ago only few of these regions were more than lightly exploited. Since then the introduction of industrialized fisheries has rapidly changed the status of most shelves from potential to overfished fishing areas. The result of this is mainly waste of resources through deployment of excessively large fleets and depletion of the more valuable stocks, with lower-valued short-lived species now dominating.

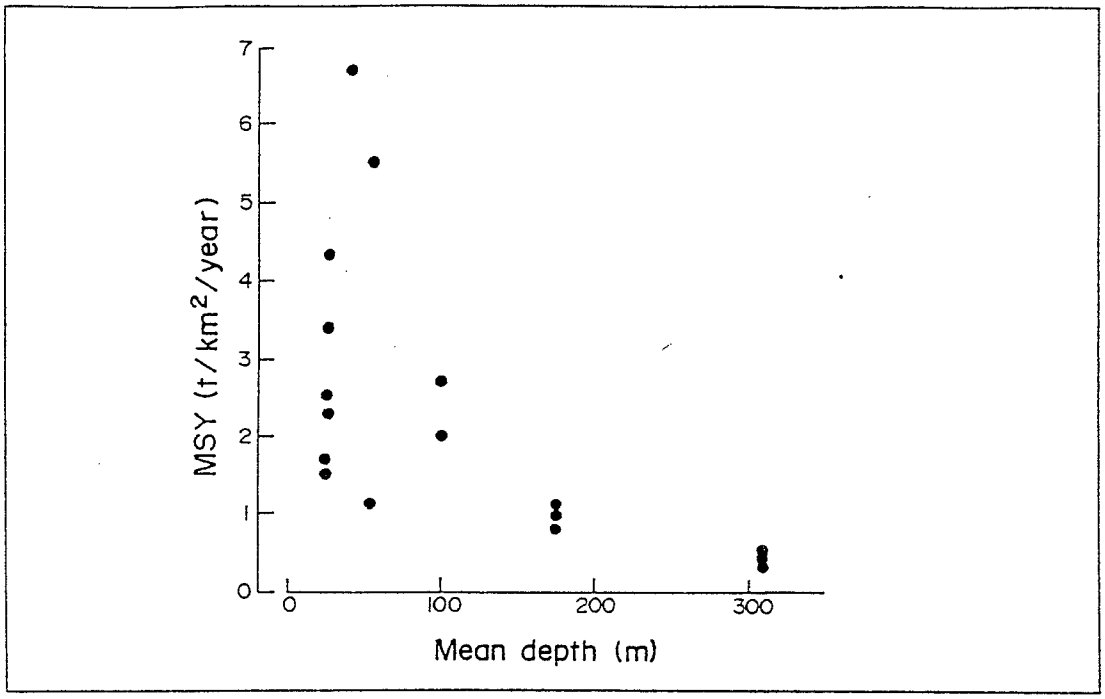


Fig. 8. Maximum sustainable yields (MSY) and depth of continental shelf demersal fisheries, based on Table 7. (Source: Marten and Polovina 1982)

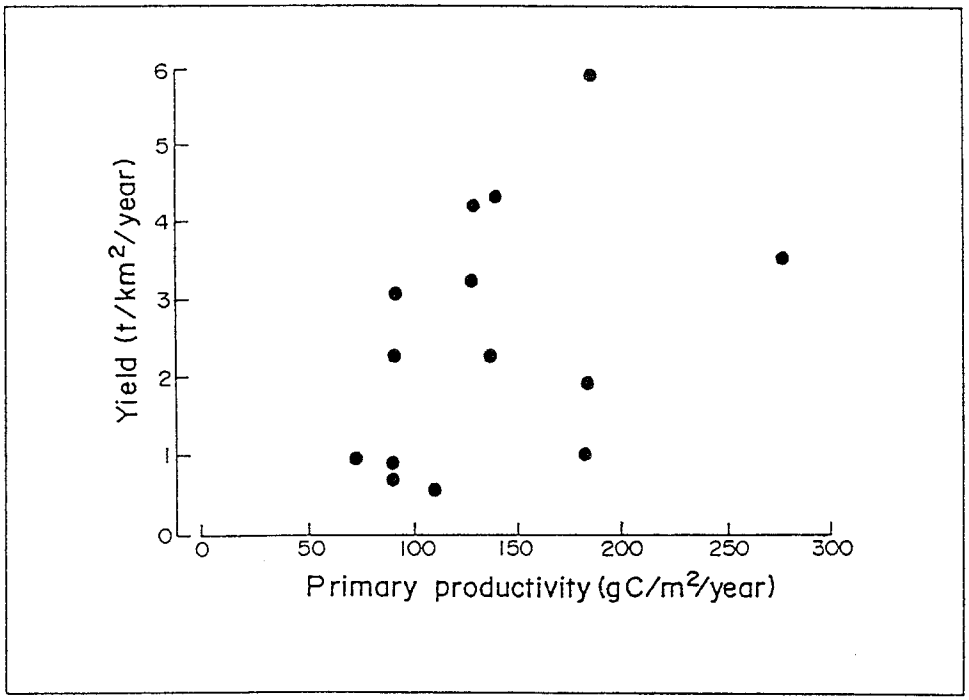


Fig. 9. Maximum sustainable yield and primary productivity of continental shelf pelagic fisheries, based on Table 13. (Source: Marten and Polovina 1982)

Due to the present nearly total lack of management of trawl fisheries in the developing world and their subsequent overexploitation, it is likely that catches can be increased by proper management. To do so it is essential to introduce new management strategies.

Table 5. Summary of estimated catches for the major resource systems for tropical and subtropical fisheries (excluding aquaculture production). Catches are in million tonnes per year. Areas in million km², and production in t·km⁻²·year⁻¹.

| | Catch | Area | Production | Comment | Assessment of potential for increases[b] |
|---|---|---|---|---|---|
| Uplands | - | - | - | Catches insignificant | - |
| Ponds | - | - | - | Catches insignificant | - |
| Reservoirs, lakes | 1.8 | 0.3 | 6.0 | 1/3 of total freshwater catch | + |
| Floodplains, rivers, swamps | 3.5 | 0.6 | 5.8 | 2/3 of total freshwater catch | - |
| Estuaries, bays, lagoons | 5.1[a] | 0.7 | 7.7 | | + |
| Coral reefs | 6.0 | 0.6 | 10.0 | From Smith (1978) | ++ |
| Shelves, softbottom | 11.1[a] | 1.5 | 7.7 | | + |
| Shelves, upwelling areas | 14.0 | 0.7 | 20.0 | FAO statistics | + |
| High seas | 3.1 | - | - | FAO statistics | + |
| Total | 44.7 | | | FAO statistics | |

[a] Catches for estuaries, etc. and softbottom shelves are estimated as the difference between total catches and the catches in the other resource systems, attributing 50% of the difference to softbottom shelves and 50% to estuaries, etc. and coral reefs.
[b] - = no significant increase possible; + = small increases possible; ++ = moderate increases possible.

(h) Shelves with upwelling

Based on data in Gulland (1971), the total area of shelves with upwellings has been estimated to be 0.7 million km². The MSYs for two upwelling fisheries are given in Table 4. The productivity of these systems is very high, comparable to the most productive aquatic systems. Due to the large areas over which upwelling takes place this makes upwelling fisheries the most productive overall.

The fish stocks in the upwelling areas are very much affected by environmental conditions. This has, for all the major stocks in upwelling areas, led to total collapses of the fisheries, and not always in combination with severe overfishing.

The upwelling fisheries are described in more detailed in the regional descriptions (Section V).

(i) Open oceans

The open oceans are fished by few developing countries (most notably Thailand), mainly for tunas. The resources of tunas and squids in the oceans are large, and expansion of these fisheries seems possible. The catch possibilities are discussed further in section VI.

(j) Generalizations

A summary of the estimated catches for the major resource systems in tropical and sub-tropical areas is given in Table 5. Ranked by total catches, the shelves with upwelling are highest, closely followed by shelves with soft bottom, and coral reefs, coastal areas, open ocean and freshwater systems following.

The yield of a resource system is related to the magnitude of the primary production. This is shown in Fig. 10 where the range and modal values of fish yield are presented as a function of the primary productivity. The yield is also influenced by other factors, e.g., the structure of the food web.

The effectivity in transfer of matter from the primary producers to the catches differs between resource systems. This is shown in Table 6. The geometric means of the observed ranges vary by a factor of 180 from the most to the least efficient.

Table 6. Ratio of fish yields to primary productivity. (Source: Modified after Marten and Polovina 1982)

| Ecosystems | Range | | | Geometric mean | Ratio |
|---|---|---|---|---|---|
| Coastal upwelling | .005 | - | .013 | 0.0081 | 180 |
| Rivers | .005 | - | .01 | 0.0071 | 150 |
| Ponds | .001 | - | .01 | 0.0032 | 71 |
| Lagoons and estuaries | .0008 | - | .01 | 0.0028 | 62 |
| Continental shelf | .0003 | - | .003 | 0.00095 | 21 |
| Lakes | .0004 | - | .0016 | 0.00080 | 18 |
| Reservoirs | .0002 | - | .002 | 0.00063 | 14 |
| Coral reefs | .0002 | - | .0008 | 0.00040 | 9 |
| Open ocean | .00001 | - | .0002 | 0.000045 | 1 |

The proportion of primary production that is eventually harvested is to a large extent a function of the number of trophic levels in the systems. A factor of 180 corresponds more or less to two steps up the food chain. In the most efficient system, the coastal upwelling system, the fishery is mainly based on catching small pelagic fish that feed on the primary producers directly or on herbivores. In the least efficient system, the open oceans, the fisheries are predominantly based on the top predators. This fact offers some possibilities for increasing the catches; changing the fishing pattern can increase the amounts landed considerably.

It is difficult to quantify the potential increases in fish catches by resource systems. A major reason for this is that few before us have used the resource system approach; also that the traditional fish stock assessment models cannot cope with radically changed fishing regimes. Following the traditional approach - unchanged fishing patterns in exploited areas - the potentials can be quantified, albeit roughly. We will discuss this further in Section VI, dealing with *regional* catch trends and potential on a global scale.

## VI. Global Trends in Regional Fish Catches

The global production of fish has been increasing steadily over the last 25 years (Fig. 11), in what appears to be three stages: Increasing catches in the 1960s due to increased exploitation of upwelling and

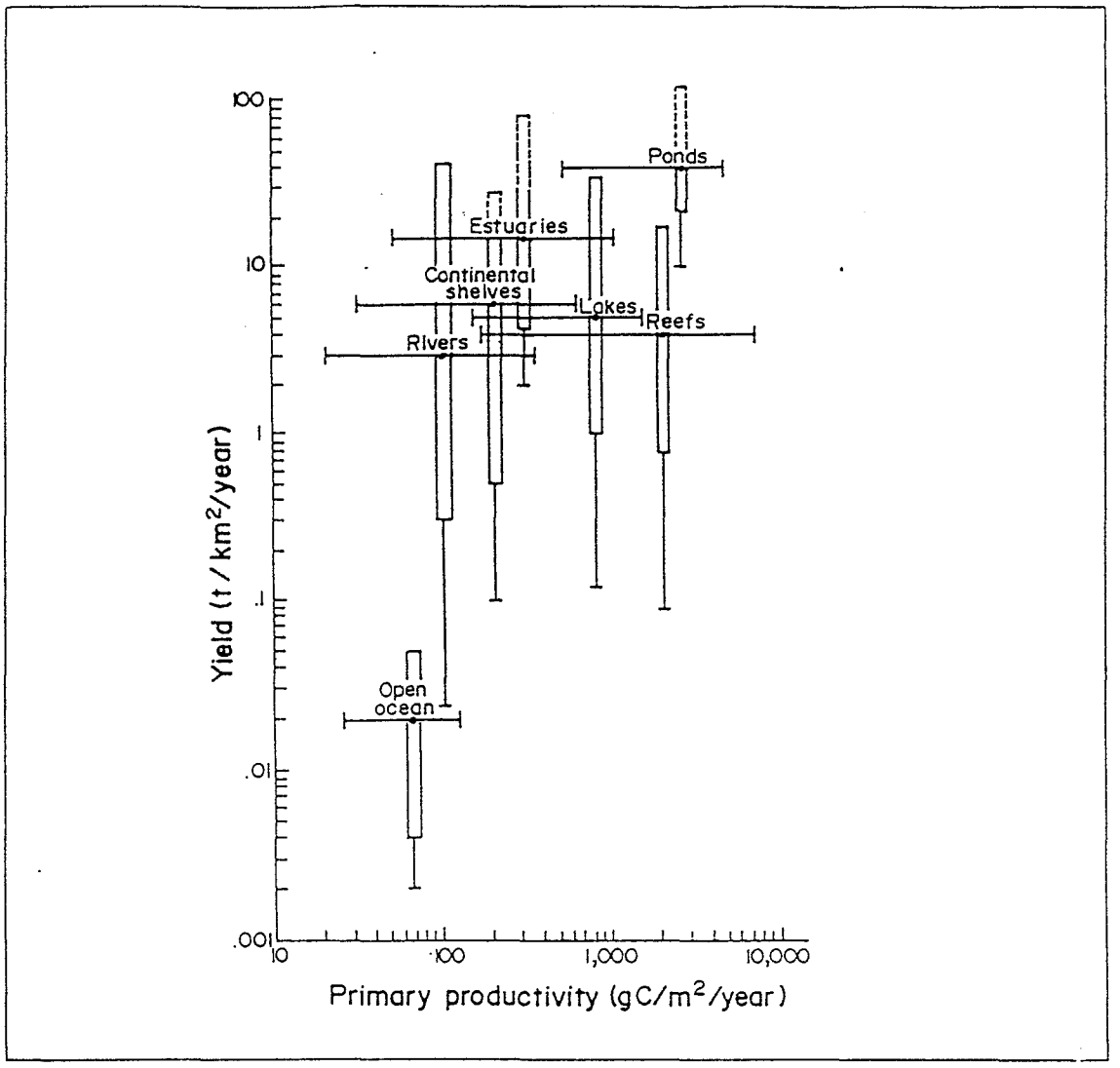


Fig. 10. Ranges of fish yields and primary productivities in various tropical ecosystems. Dots at the intersection of ranges represent modal values. Solid portions of the bars represent the range of maximum sustainable yields. Dashed projections at the top of the ranges for estuaries and ponds represent elevated yields from aquaculture with fertilization (but not supplemental feeding). The dashed projection for continental shelves represents higher yields which occur in areas of upwelling. (Source: Marten and Polovina 1982).

coastal fisheries. Stagnation in the 1970s when the Peruvian anchovy collapsed, and a gradual increase in the 1980s mainly due to increased catches of shoaling pelagic species (FAO 1990).

The bulk of the fish catches is taken from continental shelves (i.e., from water depths of less than 200 meters, generally at depths of less than 50 meters). Most of this production comes from the highly productive temperate and subpolar continental shelves in the northern hemisphere and in upwelling areas (Table 7).

The world catches are approximately evenly distributed between developed and developing countries (Table 8). Developments from 1978 to 1988, however, show a trend toward increasing production in developing countries. Total annual fish production in these countries rose 57% over the decade. The share of the total catches taken by developing countries increased in this period from 46% to 53%. The major

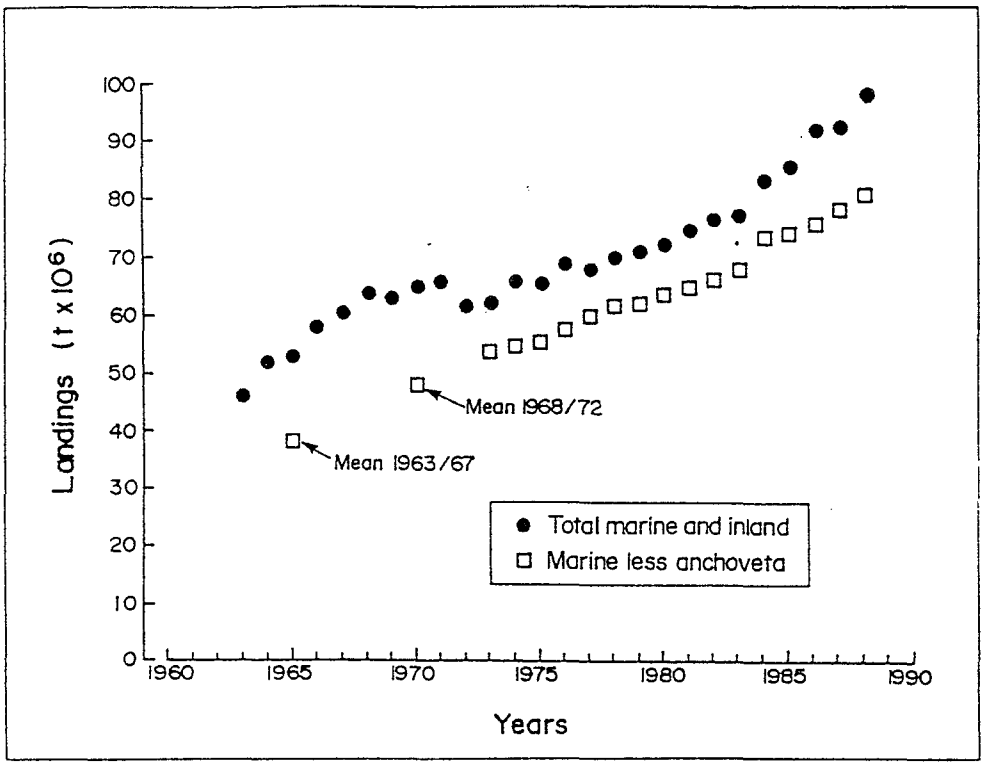


Fig. 11. Annual world landings of aquatic resources (excluding mammals and plants). (Source: FAO 1990)

Table 7. Fisheries yield ($10^3$ tonnes), by continent, 1978 and 1988. Aquaculture production is included.

| | Inland | | Marine | |
|---|---|---|---|---|
| | 1978 | 1988 | 1978 | 1988 |
| Africa | 1,467 | 1,802 | 2,831 | 3,508 |
| America, North | 152 | 564 | 6,121 | 9,004 |
| America, South | 213 | 368 | 7,063 | 14,045 |
| Asia | 4,509 | 9,188 | 27,115 | 34,414 |
| Europe | 295 | 484 | 12,336 | 12,391 |
| Oceania | 25 | 24 | 311 | 863 |
| USSR | 733 | 996 | 8,197 | 10,336 |
| Other | - | - | 1,011 | - |
| Total | 7,394 | 13,426 | 64,985 | 84,561 |

[a]From FAO statistical yearbook.

Table 8. Nominal marine and inland water fish catches (million tonnes per year) by FAO regions, 1978 and 1988. Aquaculture production is included. (Source: FAO yearbooks)

| Region | 1978 | 1988 |
|---|---|---|
| Northwestern Africa | 0.4 | 0.8 |
| Western Africa | 1.5 | 1.4 |
| Central Africa | 0.4 | 0.5 |
| Eastern Africa | 0.8 | 1.1 |
| Southern Africa | 0.4 | 0.0 |
| Northern America | 0.1 | 0.2 |
| Central America | 0.9 | 1.5 |
| Caribbean | 0.3 | 0.3 |
| South America, Pacific | 5.5 | 12.6 |
| South America, Other | 1.7 | 1.8 |
| Near-East (Africa) | 0.1 | 0.3 |
| Near-East (Asia) | 0.7 | 1.2 |
| Southern Asia | 3.5 | 4.7 |
| East & Southeast Asia | 9.3 | 12.8 |
| China | 4.7 | 10.4 |
| Asia, Other | 2.7 | 2.6 |
| Oceania | 0.1 | 0.2 |
| Developing countries | 33.2 | 52.3 |
| Developed countries | 38.1 | 45.7 |
| World total | 72.4 | 98.0 |

proportion of the increased catches in the developing countries can, however, be attributed to the upwelling fisheries (Peru/Chile; Morroco/Mauritania/Senegal; and Angola/Namibia) and to a doubling of the nominal Chinese production.

A separation of the global production of the eight major fish commodity groups is presented in Fig. 12 for 1978 and 1988. The increases in catches over the decades seem to be distributed over nearly all commodity groups, though predominantly for freshwater fishes, small pelagics and invertebrates.

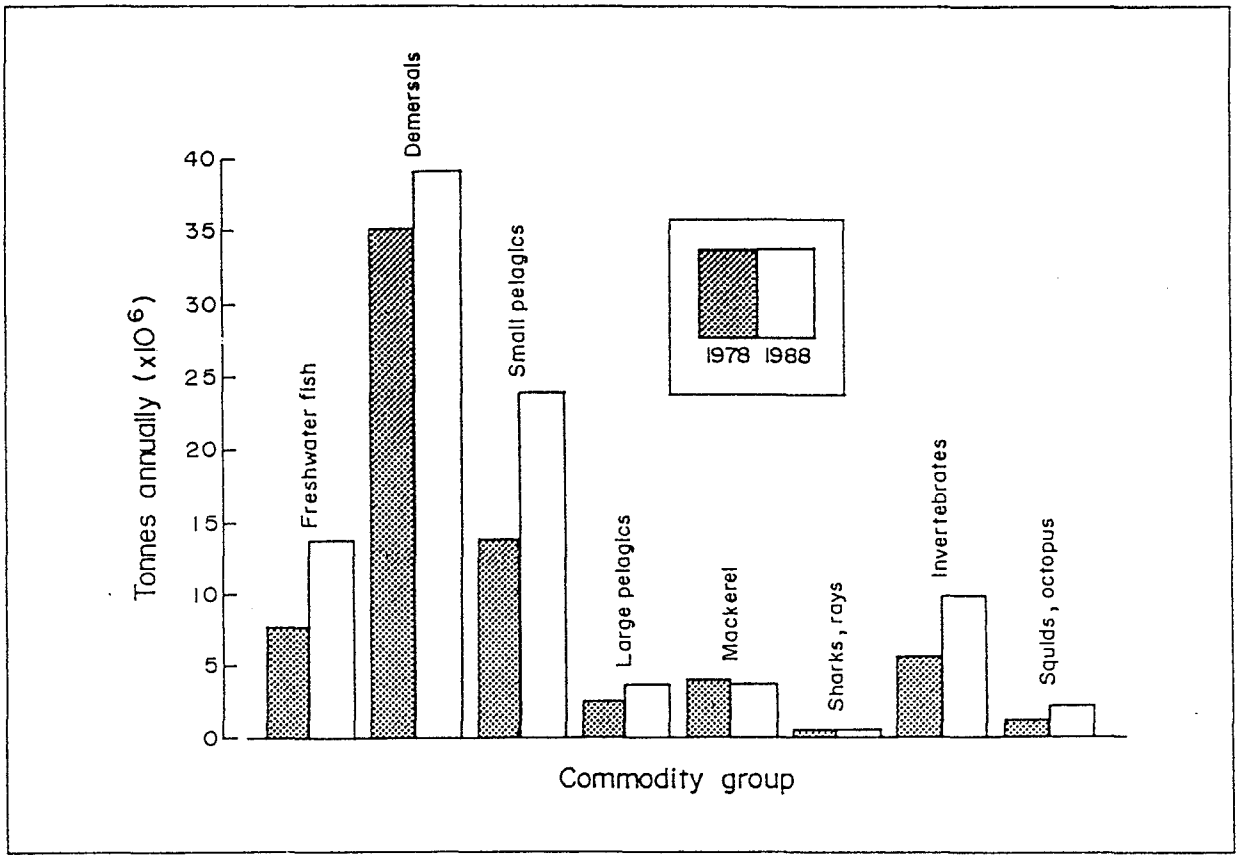


Fig. 12. Global fish production in 1978 and 1988 by major commodity groups. Aquaculture production is included. Expressed in million tonnes.

The major fishing nations among the developed countries can be arranged in three groups: *(i)* the nations bordering the North Atlantic, mainly fishing within their respective EEZ boundaries; *(ii)* the East European countries, with large, but now rapidly diminishing distant-water fisheries; and *(iii)* Japan, whose large regional fishery is supplemented by huge overseas catches taken worldwide.

The developed fishing nations previously took a large proportion of the potential catches off the coasts of developing countries. This pattern is now changing through the introduction and subsequent enforcement of 200-nautical-mile (nm) EEZs. The developing countries with the potential for large offshore fisheries will need substantial management support to utilize their offshore resources optimally.

The fisheries of developing countries can also be categorized into three groups: *(i)* the upwelling fisheries, mainly west of South America, and Northwest and Southwest Africa where there is a large potential

for increased catches through improved management; *(ii)* local commercial fisheries within EEZ areas; and *(iii)* small-scale fisheries whose catches are predominantly for local use. In addition, South Korea and Taiwan have taken up the Japanese practice of fishing overseas and operate large distant water fleets.

The best (most comprehensive) sources of catch information are the FAO fishery statistics yearbooks. The quality of the data contained therein is variable, especially for the small-scale fisheries of developing countries. Fortunately, this has improved over the last decades, and a larger proportion of catches is now reported or otherwise estimated. These improvements in the quality of the catch statistics make it difficult to assess global trends in fish production.

In the following we will give a brief overview of the fisheries in the major FAO regions of the world (Fig. 13).

### North Atlantic (FAO Regions 21 and 27)

These regions support some of the highest fish production globally, being that part of the world with the most developed traditions for large-scale fisheries. A large proportion used to be taken by high-sea fleets fishing mainly for cod. With the introduction of 200-nm EEZs this tradition has been broken and national fisheries are now dominating.

For the North West Atlantic, FAO (1981) estimated the total potential for demersal fisheries to be 2.5 to 3.5 million tonnes per year, and for pelagic fisheries some 2.0 million tonnes. The present catches are 3.8 and 0.6 million tonnes per year, respectively. This seems to suggest some basis for expansion of the pelagic fisheries, the traditional demersal stocks being fully utilized. Additionally, there may lie possibility of an expansion in fisheries for less traditional resources as redfish and silver hake by fishing deeper. FAO (1990) reports the Atlantic mackerel to be underexploited, the present catches being only 25 % of those 20 years ago.

All the major (traditional) stocks in the North East Atlantic region are fully exploited or overexploited. The potential for the region is suggested by FAO (1981) to be some 16 million tonnes annually. The difference between potential catches (which may be over-optimistic) and present catches (10.5 million tonnes) is due to nonconventional stocks, which are difficult to exploit, and to depleted stocks, which are presently nonproductive. This is indicated by the catch trends over the last decade, which have dropped from 11.9 million tonnes in 1978 to 10.5 million tonnes in 1988. This stresses the need for better management even in this area, the cradle of fisheries biology.

### Western Central Atlantic (FAO region 31)

The best known fisheries in this region are the penaeid shrimp fisheries in the Gulf of Mexico and the Atlantic/Gulf menhaden fishery. Of these the shrimp play an important economic role, while the substantial (US) catches of menhaden are mainly used for reduction, and thus are of less economic importance. The overall fish production is low and the two countries concerned (USA, Mexico) are not to

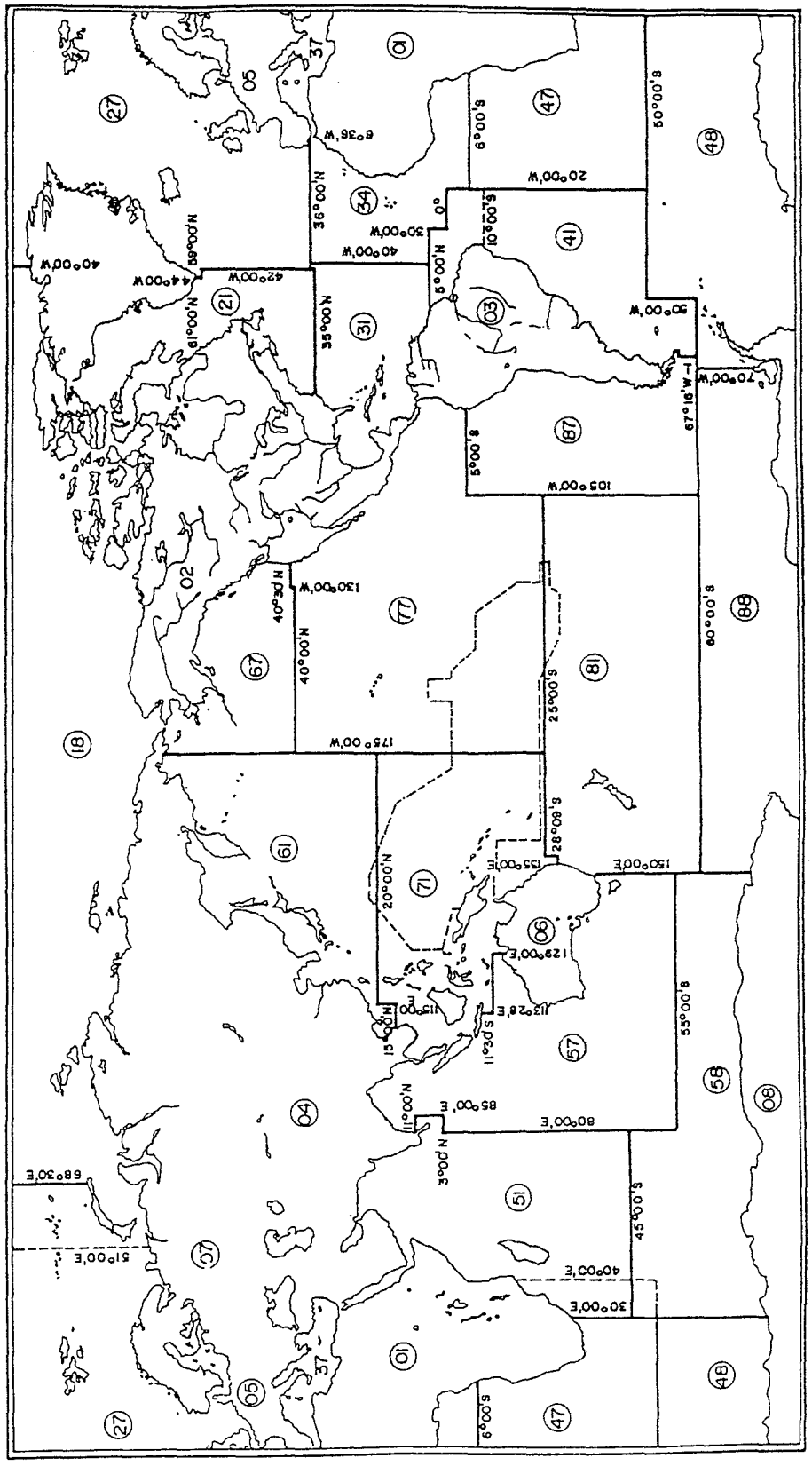

Fig. 13. Geographic boundaries of the major fishing FAO areas. (Source: FAO 1990)

any large extent dependent on these fisheries.

The potential for demersal catches in the region is estimated by FAO (1981) to be 2.5 to 3.5 million tonnes annually, comprising a variety of species, to which should be added a potential of 2.0-3.5 million tonnes of pelagic fishes and some 0.4 million tonnes of invertebrates annually. The corresponding catches are presently around 0.4, 0.7, and 0.5 millions tonnes, respectively, indicating a potential for increased catches of especially the demersals. Newer FAO reports (1990), however, conclude that the demersal stocks are fully exploited and that any substantial increases must come from fisheries on small pelagics, the largest migratory oceanic pelagics, and cephalopods. The catches from the region have remained stable at around 2 million tonnes annually over the last decade.

The region is to some extent dominated by a massive American presence. A sign of this is that sport fisheries contribute up to 20 % by weight of the total landings in the region (Couper 1983). The sport fisheries are an influential factor for management, forcing managers to maintain a large stock of apex predators (tuna, billfish, etc.) in contrast to the aim of management in most other areas.

### East Central Atlantic (FAO region 34)

The traditional fisheries in this area have been small-scale coastal fisheries. The rich offshore fishing grounds, especially off West Africa, have so far been exploited by industrialized nations, mainly from East Europe and Spain. This is now gradually changing and especially Morocco and Senegal now take a good part of their resources. The main resources are located within the 200-nm EEZ, but several of the nations in the region have their offshore-derived income mainly from fishing licenses.

The largest resources are pelagic stocks - sardine and European pilchard. The total catches of pelagics are around 2 million tonnes annually, below the potential of 3.5-4.0 million tonnes suggested by FAO (1981). The present catches of demersal fish in the region are of the order of 1.0 million tonnes annually, corresponding to the potential suggested by FAO (1981). The total catches from the region have increased from 3.0 to 3.6 million tonnes annually over the last decade.

The northern part of the region illustrates the effect of lack of proper management. FAO (1990) gives catches and estimated potentials for stocks in the region (Table 9) together with an evaluation of the state of the stock. The table includes all stocks where both potential and catch are quantified. The stocks are all considered overexploited, and yet the catches are a fraction of the potential. A phased decrease of overall fishing pressure, especially on juveniles, imposition of closed seasons, changes in the mixture of deployed gears, etc., would help rebuild the stocks, from which far greater catches could then be extracted.

### Mediterranean and Black Sea (FAO region 37)

The total fish production in this region amounts to around 2 million tonnes annually, including aquaculture production. The potential seem nearly fully exploited, and FAO (1990) reports that potential

Table 9. Annual capture fisheries yields and potentials of various fish stocks off northwestern Africa. (Source: FAO 1990)

Area: East Central Atlantic, Northern part

| Stock | Catch | Estimated potential | Catch potential | State of exploitation |
|---|---|---|---|---|
| Octopus | 42 | 100-135 | 0.31-0.42 | Grossly overexploited |
| Cuttlefish | 10 | 30-40 | 0.25-0.33 | Overexploited |
| Squids | 2 | 20-40 | 0.05-0.10 | Overexploited |
| European pilchard | 320 | 1,000 (variable) | 0.32 | Possibly fully exploited |
| Sardinellas | 153 | 600 (variable) | 0.26 | Intensively exploited, locally overfished |
| Horse mackerel | 58 | 400 (variable) | 0.14 | Possibly fully exploited |
| Mackerels | 12 | 6-12 | 0.12 | Fully exploited |
| Hakes | 6 | 6-12 | 0.5-1.0 | Grossly overexploited |
| Sea breams | 23 | 150 (?) | 0.15 | Probably overexploited |

increases would be mainly for small pelagics. The total production from the region has over the last decade increased from 1.2 to 2.0 million tonnes annually.

South West Atlantic (FAO region 41)

This region includes Brazil, Uruguay, and Argentina. It is not a major fishing area; the catches though increasing total only some 2.2 million tonnes annually. The fisheries take place within the EEZs, and the catches by noncoastal states in the region are negligible.

The main demersal species in the area is Patagonian hake for which the potential catches are reported by FAO (1981) to be within the wide range of 0.5 to 1.8 million tonnes annually, indicating the need for additional research. The total potential for demersal resources in the area is estimated at 2.5 million tonnes annually, while the present catches are of the order of 1.1 million tonnes. The pelagic fishes in the region are mainly anchovy and sardine, the potential catches of which are estimated to be 1.2 million tonnes annually. The present fishery harvests less than 1/10 of this potential. The population dynamics of the other pelagic stocks in the SW Atlantic are unknown, and the potential catches have not been estimated.

The fishery in the region increased over the last decade from 1.4 to 2.2 million tonnes annually. It seems that the region offers substantial potential for expansion of the marine fisheries.

South East Atlantic (FAO region 47)

The region includes Angola, Namibia and South Africa. The commercial fishery in South Africa was initiated at the turn of the century and was then based on Cape hake. There are some small-scale and sport fisheries along the coastlines.

The fishery in the area shows fluctuations between years, mainly the result of dependence on a few species with variable recruitment, notably anchovy and Cape horse mackerel. These two species, together with hakes and sardinellas made up 85% of the total catches in 1988.

The region contains highly productive areas off the western coast. The resources were previously utilized mainly by distant fleets, especially from Eastern Europe and Spain. The pattern has now changed as in most parts of the world, and the local nations are now dominating the catches, taking 57% of the catches (FAO 1990). Fishing by distant-water fleets in the 200-nm EEZ off Namibia has since ceased completely.

The potential catch of demersal resources (predominantly Cape hake) in the SE Atlantic is estimated at 1.0-1.4 million tonnes annually, of which the majority is presently taken. The pelagic fishery off South Africa is based on catches of anchovy, horse mackerels and sardinellas. The previously important pilchard fishery has now collapsed. The total potential for pelagics is estimated at 2.5 million tonnes (FAO 1981) of which presently only half is taken.

The total fishery in the region is reported to have decreased from 3.3 to 2.5 million tonnes annually over the last decade. Expansion of the pelagic fishery is dependent on improved management, based on biological and environmental information.

### Western Indian Ocean (FAO region 51)

This is the second largest FAO region, comprising more than 30 million km$^2$. The fishery throughout the region is of a small-scale character. Overseas fleets are limited to tuna vessels from South Korea and increasingly, Europe and Japan.

The potential catch of demersal resources in the West Indian Ocean is estimated by FAO (1981) to be more than 2.6 million tonnes annually. The present catches are around half the potential, indicating possibilities for expansion. For the pelagic groups, the estimates of potential resources are very uncertain as estimates are missing for several important areas. The potential seems, however, to be of the order of 3 million tonnes annually. The pelagic catches now are around 1 million tonnes, a large proportion of which is tunas. The total catches have increased from 2.3 to 2.9 million tonnes over the last decade.

Overall the FAO statistics points at potential additional catches of perhaps more than 3 million tonnes annually. Most of this potential occurs in coastal areas of less than 70 meters depth. Additional large unexploited resources of mesopelagic fish have been detected, but no economically viable way of harvesting these resources has been developed.

### Eastern Indian Ocean (FAO region 57)

The countries in this region constitute a very diverse group. In the northern part of the region the fishery is mainly small-scale, while in the south there are highly industrialized fisheries. The fishery by overseas fleets in the region is small.

Only very limited information is available on the stock sizes in the region. Tentatively, the potential can be estimated at 2 million tonnes of demersals and 1-2 million tonnes of pelagics annually. The present catches are around 1.5 million tonnes of demersal finfish, and 0.6 million tonnes of pelagic finfish. The total catches have gone up over the last decade, from around 1.3 to 2.7 million tonnes annually.

The additional catches that can be added to the present ones seem to be of the order of 1-1.5 million tonnes annually. This estimate is, however, highly uncertain due to the generally low level of assessment and management of fish resources in the area. Many coastal pelagic stocks, both small and large species, seem to be lightly exploited in the northern part of the region (FAO 1990).

### North West Pacific (FAO region 61)

This is the most productive region of the world, with catches amounting to more than 1/4 of the world total.

The large fisheries of Japan and China are well established, and have more recently been supplemented by a large Soviet and Polish fishery in the region. China, Taiwan, Vietnam and the Korean states together make up the most important small-scale fisheries in the world. The traditional fishing pattern in China is in marked contrast to the highly developed fishery conducted by Japan, which operates the largest commercial fishing industry in the world, fishing the seven seas. The Japanese development has been followed by South Korea and Taiwan.

Total fish production in the area has increased from 18.9 to 26.7 million tonnes annually over the last decade. This substantial increase is mainly caused by an increase of nearly 6 million tonnes annually in the Chinese production.

Serious overfishing is seen in many demersal stocks in the southern part of the area, including the Yellow Sea and East China Sea. The stocks of commercially valuable demersal stocks here are now estimated to be one-tenth to one-fifth of their previous levels (FAO 1990). Some offshore stocks offer potential for increased catches, most other stocks in the area are considered nearly fully exploited. Higher catches will require improved management.

### North East Pacific (FAO region 67)

The fisheries in this region developed within the last century. The possibility of exporting fish to the large markets in the eastern USA quickly led to overexploitation of some of the more vulnerable fish species. Consequently the International Halibut Commission was established in 1924 and it became the first international body to regulate a fishery with some success.

The potential catches of demersal fish in the region are estimated by FAO (1990) to be only a few hundred thousand tonnes higher than the present catches of some 2.7 million tonnes annually. The demersal resources consist mainly of Alaska pollack, pacific cod, yellowfin sole and rock sole.

For the pelagics, the only notable possibility of increased catches seems to come from the herrings, where perhaps an additional few hundred thousands tonnes can be caught annually (FAO 1981). The pelagic catches are now just over 400 thousand tonnes annually, most being salmon.

The total catches have increased from 1.8 to 3.3 million tonnes annually over the last decade, mainly due to increase in the demersal catches.

### Western Central Pacific (FAO region 71)

This area is characterized by high productivity of the ocean, a high number of small-scale fishers and rather steady catches over the last decade (6.1 to 6.5 million tonnes).

The potential demersal catches are estimated by FAO (1981) at 4-5 million tonnes annually while the catches presently amount to 3.2 million tonnes. The coastal areas are overexploited throughout the region, while the pelagic stocks are probably underutilized, especially in Eastern Indonesia. FAO's (1981) estimate is a potential production of 4-5 million tonnes annually, or around twice the level of the present catches of some 2.3 million tonnes per year. The shrimp fishery in the region takes around 400 thousand tonnes annually (and hundreds of thousands of tonnes of bycatch which are mainly discarded), while some 180,000 tonnes of cephalopods are caught annually. The cephalopod stocks are considered only slightly to moderately exploited (FAO 1990).

Fishing by distant water fleets is a feature of the region. Several South Pacific and Asian countries have joint venture or access agreements with distant water fleets, especially from Japan and the USA.

In the shallower areas increased catches can only be expected if the management is improved. The need for reduced fishing effort, mesh size regulations, and closed seasons is emphasized (FAO 1990).

The demand for fish for the local markets is steadily increasing as a result of growth in populations. The consequences are likely to be coastal stocks that are even more overexploited, and expansion of the industrialized fisheries.

### Eastern Central Pacific (FAO region 77)

This region includes an eastern ocean boundary that supported a major fishery for Californian sardine with peak catches of over 1 million tonnes annually in the 1930s. The fishery collapsed in the 1950s, but since the 1970s gradually increased to close to 500,000 tonnes annually. While depleted, the niche of the sardines was taken over by lower valued anchovies, as also seen in other areas.

FAO (1981) reported the potential yield of the demersal resources in the region at some 1 million tonnes annually, mainly of coastal hake. The catches in the late 1980s were around 1/4 of this estimate, suggesting possibilities for increased yields. For the pelagic stocks (excluding tunas) the estimates of potential yield amount to 2.0-2.5 million tonnes annually. The present catches are some 1.3 million tonnes per year. Noting previous catches of 1.0 million tonnes of sardines annually, and the close connection

between climate and pelagic stocks in this region, it needs to be stressed that proper management is essential to maintain and/or increase the catches.

Potential increases of perhaps 300-400 thousand tonnes annually of catches of skipjack tuna and albacore seems possible (FAO 1990). The total tuna catches are currently around 500,000 tonnes per year.

The cephalopod catches in the region are estimated to have a potential of around 1.0 million tonnes annually, mainly of jumbo squid. The catches are now over 100,000 tonnes annually and increasing - by a factor of five over the last decade. FAO (1990) indicates that there are also potential (US) catches of half a million tonnes annually of unexploited stocks of crabs.

The catches by distant fleets in the area are limited to offshore tuna and squid fisheries.

In summary the catches from the Eastern Central Pacific offer a potential for expansion. The last decade has shown an increase from 1.7 to 2.4 million tonnes annually. To continue the increase good management is essential; especially for the small pelagics. The offshore exploration of tunas, mackerels and squids is probably the only viable way of utilizing the gigantic quantities of mesopelagics in this area, the largest FAO region.

South West Pacific (FAO region 81)

The major fisheries (in bulk) in the region are carried out by the highly industrialized Australian and New Zealand fleets. On the small Pacific islands, artisanal fisheries are of major importance for the subsistence of the local populations. On many islands, community-based management has been successful in maintaining the predominantly reef-based fisheries in a healthy state.

The demersal fisheries in this region are suggested by FAO (1981) to have a potential of around 1.0 million tonnes per year. The total catch of demersal fish presently is estimated to be around 3/4 of this, indicating slight possibilities for increase.

For the small pelagics, the potential is estimated at another million tonnes annually; present catches are small (1/10 of the estimated potential). Additional potentials of other pelagics have not been estimated. The present catches are of less than a hundred thousand tonnes annually.

Catches of cephalopods have been around 100,000 tonnes per year for the last decade. As the cephalopod stocks are considered only lightly exploited, possibilities of expansion exist, especially in the offshore areas (FAO 1990).

The past decade has seen a major increase in catches, from some 0.3 million tonnes annually up to a million tonnes.

South East Pacific (FAO region 87)

The upwelling fisheries off Peru and Chile are famous for high production and bad management. The catches of the Peruvian anchovy have in recent decades gone from over 15 million tonnes annually down

to less than 1 million. In 1988 they were around 3.6 million tonnes of anchovy, up from some 2 million tonnes the previous year, but still far less than their potential.

The fishery for pelagics off the western South American coast is the only one among the world's upwelling fisheries that is and has been conducted exclusively by developing countries.

The potential for the pelagic stocks is estimated at 4 to 12 million tonnes annually while the present catches are around 8.6 million tonnes and, as mentioned, highly varying.

The demersal stocks in the region are substantial with catches of 3.8 million tonnes in 1988, up from 1.7 million tonnes a decade before. The total catches have more than doubled over the decade, from 5.2 to 12.9 million tonnes annually.

The conclusion for the South East Pacific is that without proper management, the highly opportunistic and intensive fishing pattern one has seen in the region over the last four decades will prevent the potential from being realized.

## VII. Discussion

Table 10 gives a summary of present and potential production by FAO area. Overall potential is suggested to be around 25 million tonnes, noting that the estimates of potential production need to be updated and that potential for increasing invertebrate production is hardly discussed.

Assuming that half of the potential in regions where developed and developing countries share the resources (regions 31, 34, 47, 57, 71 and 77), and all of the potential in areas where the catches are dominated

Table 10. Potential and actual catches in the major marine FAO regions of the world. Potential catches are from FAO (1981, 1990) or set equal to present catches where these exceed the potential.

| FAO region | Area | Catches ($10^3$ t) Present | Potential | Potential increase Total | % |
|---|---|---|---|---|---|
| 21 | North West Atlantic | 4,400 | 5,200 | 800 | 18 |
| 27 | North East Atlantic | 10,500 | 16,000 | 5,500 | 52 |
| 31 | Western Central Atlantic | 1,900 | 6,400 | 4,500 | 236 |
| 34 | Eastern Central Atlantic | 3,600 | 5,000 | 1,400 | 38 |
| 37 | Mediterranean/Black Sea | 2,000 | 2,000 | 0 | 0 |
| 41 | South West Atlantic | 2,200 | 3,700 | 1,500 | 68 |
| 47 | South East Atlantic | 2,500 | 3,900 | 1,400 | 56 |
| 51 | Western Indian Ocean | 2,900 | 5,600 | 2,700 | 93 |
| 57 | Eastern Indian Ocean | 2,700 | 3,500 | 800 | 29 |
| 61 | North West Pacific | 26,700 | 26,700 | 0 | 0 |
| 67 | North East Pacific | 3,300 | 3,900 | 600 | 18 |
| 71 | Western Central Pacific | 6,500 | 9,600 | 3,100 | 47 |
| 77 | Eastern Central Pacific | 2,400 | 4,800 | 2,400 | 100 |
| 81 | South West Pacific | 1,000 | 2,000 | 1,000 | 100 |
| 87 | South East Pacific | 13,000 | 13,000 | 0 | 0 |
| | Total | | | 25,700 | 30 |

by developing countries (regions 41 and 51) can be attributed to potential catches for developing countries this suggests a potential increase of some 11 million tonnes for the marine fisheries of the developing world, not including any nonconventional resources.

How can this increase be realized? We believe this can be achieved only if each country:

- manages all its important fish stocks such that it produces something close to maximum sustainable yields (MSY);
- conserves the critical habitats that contribute to the recruitment of the stocks, i.e., the mangroves, bays, seagrasses and other nearshore nurseries on which these stocks depend; and
- conserves coral reefs and increases their production through judicious location of sanctuaries (for natural recruitment enhancement).

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