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# REVIEW OF THE STATE OF WORLD FISHERY RESOURCES; INLAND FISHERIES

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# REVIEW OF THE STATE OF WORLD FISHERY RESOURCES; INLAND FISHERIES

**by**

**Inland Water Resources and Aquaculture Service**
**Fishery Resources Division**
**Fisheries Department**

**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**
**ROME, 1999**

## PREPARATION OF THIS DOCUMENT

The last version of this review was published in 1995. This review has been timed to take advantage of the just-released capture data for 1997.

Mr Gerd Marmulla, Fishery Resources Officer (Inland Fisheries), wrote Section 3.5 on rehabilitation and mitigation aspects for inland fisheries. Mr Bram Born, former Associate Professional Officer (Inland Fisheries) prepared Section 3.4 on inland fishery enhancements from a global perspective. The remainder was written by Dr James McDaid Kapetsky, Senior Fishery Resources Officer (Inland Fisheries).

Drs Robin Welcomme, Tomi Petr, Devin Bartley, Ziad Shehadeh and Uwe Barg made valuable suggestions for improvements on the draft version.

The cover drawing is part of a sketch of cast net fishermen at Jimu Dam, Zambia by King (1992).

The design and layout of the document and adaptation of Mr. King's sketch for the cover were done by George Ellis.

Comments are welcome and should be sent to the Chief, FAO Inland Water Resources and Aquaculture Service, Via delle Terme di Caracalla, 00100 Rome Italy.

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**Review of the state of world fishery resources: inland fisheries.**
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## ABSTRACT

The purpose of this review is to present a broad view of the state of inland capture fisheries. The review is organised in three main parts. The first part is an overview of inland capture. Overall, the trend is for an annual average increase in inland capture of about 138 000 t. The nominal inland capture amounted to about 7.7 million t in 1997. Actual inland capture is considerably greater than the amounts reported to FAO. The factor is at least two overall, but may be as high as three in some instances. There is an urgent need for better data on inland fisheries that can be interpreted in both economic and ecological terms. Although the cost of improving inland fishery data collection may be high, failure to fully account for inland capture also is costly in terms of lessened, or lost, opportunities to increase food security and other economic and social benefits from inland fishery resources.

The second part deals with trends in capture organised by continental regions, sub-regions and countries for the period 1984 to 1997. Asia produces a disproportionately large share of the global inland capture in relation to its continental land area and the water surface available there. The 14-year trends are for increases in inland capture in Asia, Africa and Latin America and for decreases in the Former USSR Region, North America and Europe while Oceania is stable.

The third part sets out major issues, of which the environment is the salient concern, and future directions of inland fisheries, mainly towards increased uses of enhancements to increase outputs. Enhancements are characterised on a global basis according to type, species and geographical distribution. Rehabilitation and mitigation of inland systems are highlighted as is the importance of recreational inland fisheries.

# CONTENTS

# 1. OVERVIEW OF INLAND CAPTURE

## 1.1 Introduction

The purpose of this report is to present a broad view of the state of inland fisheries. An underlying purpose is to call attention to the need for better management of the aquatic environment and of inland fisheries as a way to sustain the resources and to increase benefits.

In contrast to recent reviews in this series (FAO, Inland Water Resources and Aquaculture Service, Fishery Resources Division. 1995), the purpose is to call attention comprehensively to global and continental issues. The last review contains much that remains pertinent regarding issues at country level; as it is still in print, that information is not repeated here. Moreover, FAO Fishery Country Profiles[1] provide another source of fishery background on a national basis that supplement the present study. Finally, a comprehensive review of inland fisheries in relation to constraints and prospects for food security was carried out recently (Coates, 1995).

Also, in contrast to previous reviews, a continental overview of inland capture is provided against a backdrop of surface water resources. Another addition is that inland capture reported to FAO is plotted by individual countries and 14-year trends are noted for each.

Finally, for the first time, sources are fully attributed.

## 1.2 Inland Fisheries in Context

Inland fisheries are complex. Inland fishery resources provide for a multitude of activities for an extensive range of purposes, undertaken by people from the widest possible spectrum of socio-economic situations, in a wide variety of environments.

In contrast with marine fisheries where the disposition of by-catch is an issue and from which a substantial portion of the capture is for industrial uses, in inland food fisheries the concept of “trash” does not exist--virtually all the caught fish is consumed.

The share of aquaculture-based fisheries is increasing and inland fisheries also are enhanced by other methods. In this and in other ways the links between inland fisheries and aquaculture are multiplying to the point that inland fishery enhancements are becoming a central theme in inland waters. For this reason a sub-section of this report is devoted to the characterisation of inland fishery enhancements.

## 1.3 Kinds of Inland Fisheries

Fishes, lampreys, amphibians, crustaceans and molluscs are taken from inland waters for a number of purposes using a broad range of fishing gears with various levels of sophistication (see Box: Definitions).

Four kinds of uses of inland waters for fisheries have been distinguished (FAO Fisheries Department, 1997a).

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[1] FAO Fishery Profiles can be accessed via http://www.fao.org/WAICENT/FAOINFO/FISHERY/fcp/fcp.htm

- Food fisheries on wild stocks depending on natural reproduction and fertility continue in most of the larger rivers and lakes of the world. Such fisheries are generally at or exceed the limits of sustainable yield and corresponding shifts in fish community structure are occurring with risks of diminished production and damaged stocks.
- Food fisheries mainly in smaller water bodies are increasingly being enhanced to raise productivity of selected species above natural levels. This type of management is spreading and the technologies are being increasingly employed in larger water bodies.
- Recreational fisheries are becoming more common in many areas of the world and, where they develop, may conflict with commercial food fisheries. Recreational fisheries may contribute to food supply in a way similar to, or in addition to subsistence or artisanal fisheries.
- Fisheries on juvenile or small adult forms that locally are very intense with the catch used for stocking into other water bodies and aquaculture ponds, or for the ornamental fish trade.

Because of the present structure of reporting fishery statistics and due to incomplete reporting to FAO (see Box: Inland Capture Statistics), this report focuses mainly on fisheries for food.

## 1.4 Inland Water Systems Producing Aquatic Living Resources

Fishes and other aquatic resources are captured from a great variety of inland systems. Among them are perennial lakes that account for about 1.7 million km$^2$ of which large lakes (> 100 km$^2$) amount to nearly 1 million km$^2$ (Kapetsky, 1998). North America possess the greatest freshwater large lake surface[2] (Fig. 1.1). Swamps, marshes and other wetlands amount to about 4 million km$^2$ of which the former USSR countries possess the greatest proportion (Fig. 1.1).

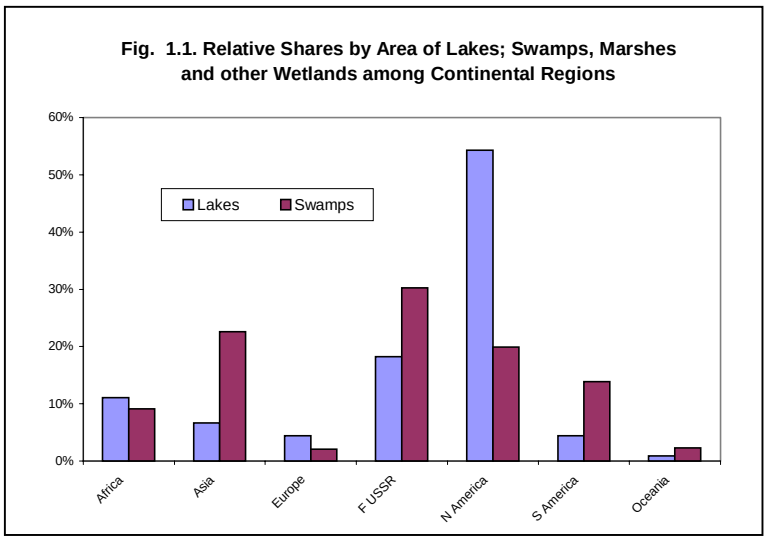


**Fig. 1.1. Relative Shares by Area of Lakes; Swamps, Marshes and other Wetlands among Continental Regions**

Main channel river lengths sum to about 269 000 km world wide. The highest density of rivers occurs in South America, the least in Oceania (Fig. 1.2).

[2] Inland saline lakes and seas in Asia make up nearly one-half million km$^2$

## BOX: DEFINITIONS

There is considerable lack of precision in the general use of terms and concepts associated with fisheries. In any analysis of global or regional food status, it is of little use to consider a simple production 'system' called 'fisheries' as a homogenous unit. Such a concept will aggregate all those various activities which exploit finfish, crustacea and molluscs. This simplification takes no account of the differences in the basic production processes, the ecosystem types exploited, technology of harvesting, or the economics of the activity.

- **AQUACULTURE**: (FAO Fisheries Department, 1997b)
  Aquaculture is defined here according to the definition currently used by FAO for statistical purposes, i.e. - "Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licenses, are the harvest of fisheries.
- **INLAND FISHERIES**[1]**:**
  Any activity conducted to extract fish and other aquatic organisms from inland waters.
- **CAPTURE FISHERIES:**
  The removal of aquatic organisms from natural or enhanced inland waters.
- **CULTURE BASED FISHERIES:**
  Capture fisheries which are maintained by stocking with material originating from aquaculture. installations.
- **ENHANCED FISHERIES:**
  Activities aimed at supplementing or sustaining the recruitment of one or more aquatic organisms and raising the total production or the production of selected elements of a fishery beyond a level which is sustainable by natural processes (also includes culture-based fisheries).
- **RECREATIONAL FISHERIES:**
  Fisheries conducted by individuals primarily for sport but with a possible secondary objective of capturing fish for domestic consumption but not for onward sale.
- **WILD FISHERIES:**
  Fisheries based on natural production and recruitment

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[1] This definition and those following are from: FAO Fisheries Department. 1997a. Inland fisheries. FAO Technical Guidelines for Responsible Fisheries No. 6. Rome, FAO. 36p.

## BOX: INLAND CAPTURE STATISTICS

The contribution of inland fishery resources to food security is certainly greatly under reported because of the dispersed and informal nature of many fisheries. For example:

It has been observed that, in general, rivers produce about twice as much capture as is reported (Welcomme, 1976). More specifically:

- Brazil reported an inland capture of about 193 000 t from all of its waters for 1991, but an independent estimate for the same year based on human population and fish consumption rates suggests about 319 000 t for the Amazon Basin portion of Brazil alone (Bayley, 1998).
- Ghana's inland waters are dominated by Lake Volta (8 000 km$^2$). Ghana reported a capture from all of its inland waters of from 55 000 to 74 000 t in recent years, but based on a partial frame survey, total production of Lake Volta alone likely to be around 150 000 to 200 000 t/y (De Graaf and Ofori-Danson, 1997).
- Cambodia has reported inland capture ranging from about 50 000 t to 75 000 t for the years 1984-1997; however, the actual range for the years 1994 to 1997 has been estimated at from 290 000 to 430 000 t (van Zalinge et al., 1998)
- Similarly, the largest annual catches reported to FAO by Thailand, Viet Nam and Lao PDR in the period 1984-1997 were, respectively, 229 000 t, 136 000 t and 26 000 t while estimates made by MRC (1992) and Jensen (1996) indicated catches of 303 000 t, 190 000 t and 27 000 t, respectively.

It has been stated that actual catches may be at least twice as high as submitted to FAO by inland fishing countries (Coates, 1995); however, as these examples suggest, and on the basis of anecdotal information from other sources, the underreporting could be even greater in many cases.

### Recreational Fisheries

Of 200 countries approached by FAO, only 30 responded with recreational capture estimates. These amounted to 476 500 t in 1990 (FAO, 1992).

### Species and Species Groups

Some 11 500 fish species (41% of all fishes) are exclusively freshwater and about 1% are diadromous. Only about 100 fish species, or species groups, are listed in FAO statistics as making up inland capture. In this regard, the quantification of the importance of individual species and of species groups as inland fishery resources is severely handicapped by the lack of reporting at these levels. Overall, some 45% of the inland catch is aggregated as "freshwater fish not elsewhere included" (nei), 7% "freshwater molluscs nei" and 6% is "crustaceans nei".

### Relevance of Fisheries Information

The main reasons for the poor knowledge of the state of inland fishery resources are the large number, dispersion, variety and dynamic nature of inland water bodies, and the diversity of their aquatic fauna. These factors give rise to fisheries that are numerous, complex and served by a wide variety of distribution and marketing systems. In turn, these characteristics mean that the collection of data is costly. Nevertheless, there is an urgent need to improve basic data gathering and reporting on inland food fisheries in quantifiable ecological and economic terms. Failure to do so can result in the following:

- Insufficient political justification by fishery administrations to invest in fishery management and to effectively protect inland fishery resources from degradation of the environment and loss of habitat
- Lack of awareness of policy makers in other sectors of the importance of inland fish and fishery resources to food security and income generation; consequently, reduced capability in the fisheries sector to compete for resources and for access to water
- Interests and needs of inland fish producers, processors, transporters and marketers often ignored, or neglected, particularly at local levels
- Lack of a suitable knowledge base for dialogue and co-operation among countries sharing inland water fishery resources and having lake and river basins in common

Not only does data collection need to be improved, but also reporting should be modified so that data, in future, can be analysed along watershed and ecoregion lines as well as, at present, by administrative boundaries. This improvement is fundamental for an ecosystems approach to fisheries management and has the added advantage that integrated management of land and water resources among many sectors is facilitated[1]. With the increasing use of geographical information systems, partitioning inland fisheries data by ecological and administrative criteria is not the daunting task that it would have been in the past.

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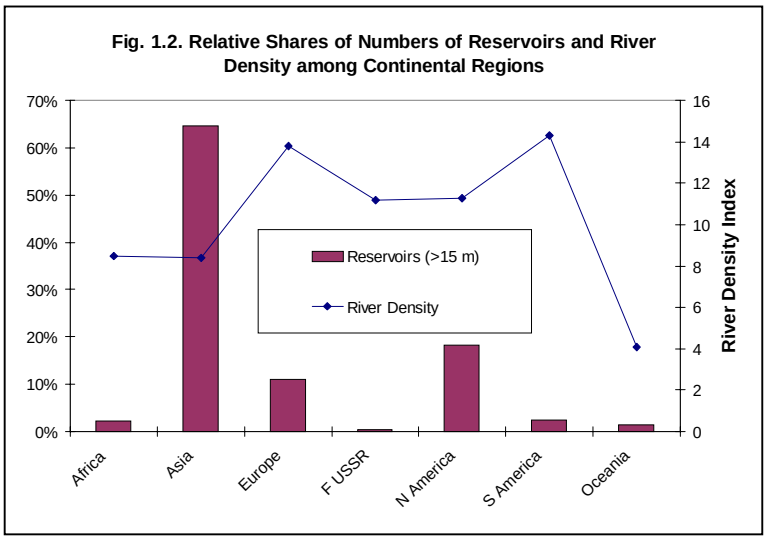
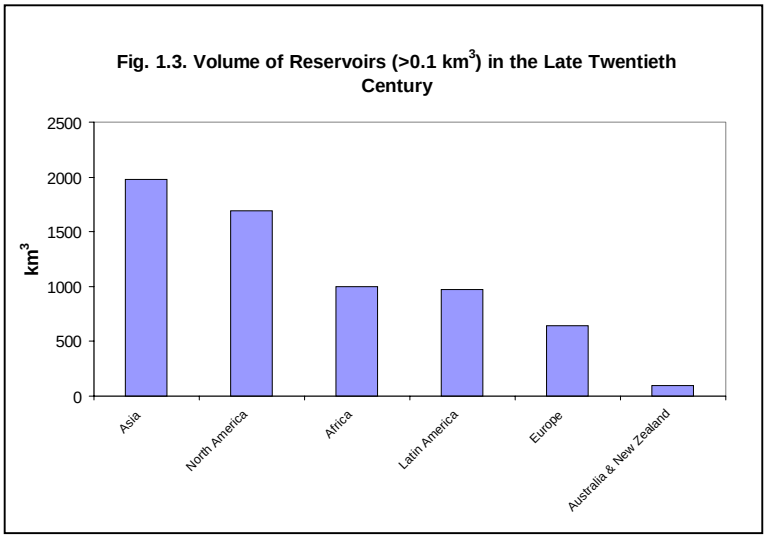
[1] "Integrated resource management for sustainable inland fish production" expands on some of the important issues raised herein including competition for resources, institutional and political support for the inland fisheries sector. It was presented to the 23rd Session of the FAO Committee on Fisheries, 15-19 February, 1999 as document COFI/99/2 and can be found on the FAO Fisheries Department web site at: http://www.fao.org/fi/news/sustain/sustainf.htm

Fished artificial water bodies range from large hydroelectric reservoirs to multipurpose community and family ponds, irrigation canals, borrow and loam pits, rice fields and roadside ditches.

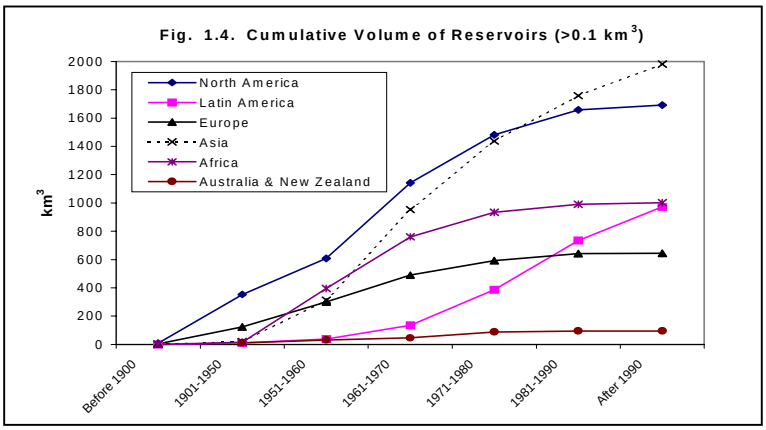
Large reservoirs (>0.1 km$^3$) are relatively recent, most dating from after World War II. The global totals are 60 000 in number, 400 000 km$^2$ in water surface and some 6 500 km$^3$ in volume (Avakyan and Iakovleva, 1998). It is remarkable that reservoir storage has attained about 7 times the standing stock of water in rivers (Vorosmarty et al., 1997).




Asia possess nearly 65% of the global total of reservoirs by number (Fig. 1.2) and 31% by volume (Fig. 1.3). Most reservoirs are in China and the surface[3] amounts to about 20 000 km$^2$.




The creation of large dams in the USA peaked in the 1950s and 1960s (Collier, et al., 1996) while in Africa it was during the 1970's (Kapetsky, 1998). Growth in volume is trailing off in North America, Africa and Europe (Fig 1.4) (Avakyan and Iakovleva op cit). There is a trend for smaller reservoirs.

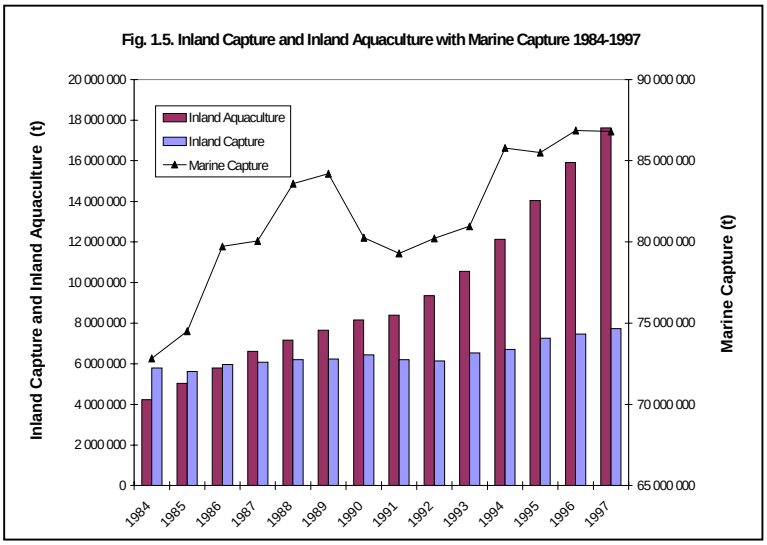



The larger, better-known reservoirs (>0.1 km$^3$) account for about 95% of the water stored in reservoirs (Avakyan and Iakovleva, 1998), but there are uncounted millions of multi-purpose small water bodies around the globe that could contribute more importantly to food production. For example, more than 14 000 small water bodies have been inventoried among 10 countries in southern Africa (Verheust, 1998;

[3] Miao, Weimin (Manuscript prepared for FAO, 1998) Documentation of inland fishery enhancements in China.

Verheust and Johnson, 1998). But, by and large, they await individual attention for the introduction of the appropriate management schemes that are compatible with the other uses.

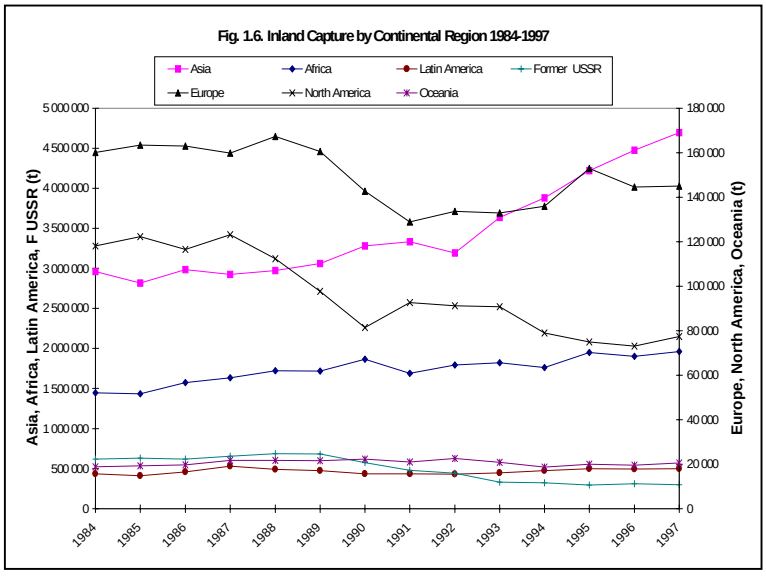
## 1.5 Inland Capture Relative to Marine Capture and Inland Aquaculture




In 1997 inland production totalled 25.4 million t of which capture was 7.7 million t (31%) and inland aquaculture the remainder. Total capture was 94.5 million t of which inland capture was 8% and the remainder marine (Fig. 1.5)

## 1.6 Overall State of Resources Indicated by Global and Continental Trends

Based on total inland capture for the period 1984-1997 it is clear that increasing use is being made of inland fishery resources. The average annual increase has been about 138 000 t (about 2%/y).

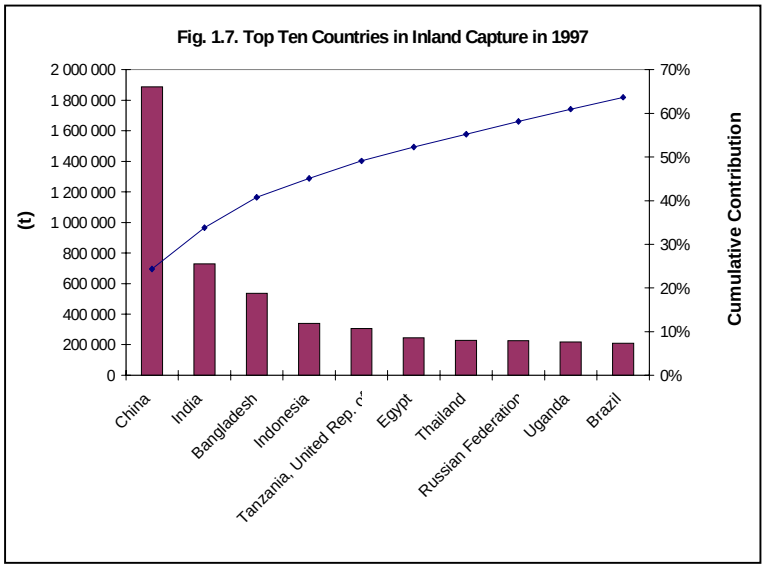



Asia is the most important continent by far, and it is Asia where the largest increases in inland resource use have been occurring with an annual average rate of increase of 4% since 1984 and 7% since 1992 (Fig. 1.6). In Africa, the second most important region, the 14-year trend is for an average annual increase of about 2%. In contrast, inland capture is on a trend for decrease in the former USSR (-7%) and in North America (-4%). In the former this decline in resource management is linked with the political and economic changes in the Region (e.g., over-exploitation of Caspian Sea sturgeon) and loss of habitat (e.g., Aral Sea). Some part, too, may be due to incomplete statistical reporting. In North America this trend may be indicative of the continued displacement of commercial fisheries by recreational

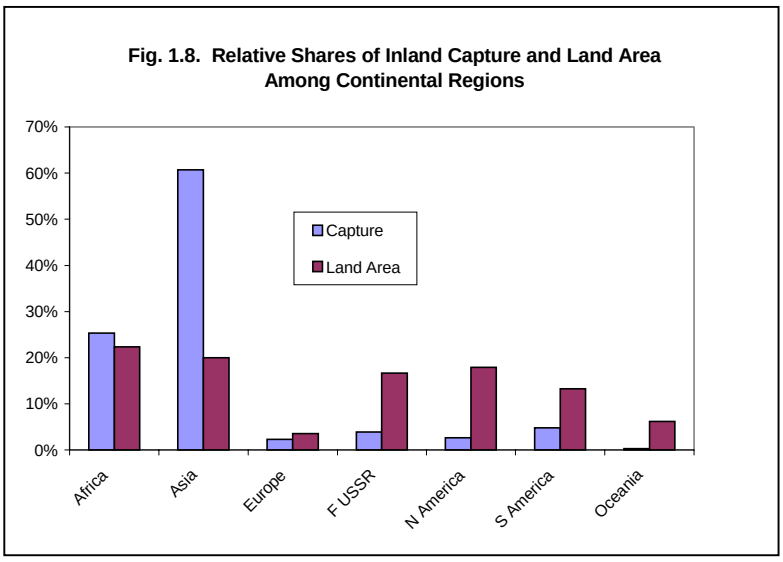
fishing. The 14-year trend for Europe also is for a decrease (-1%) while South America is increasing slightly (1%) and Oceania (0%) has been fairly stable over the long term.

## 1.7 The Most Important Inland Fishery Countries

China, with a production of nearly 1.9 million t, produces 24% of the world total and nearly three times as much as does the second largest producing country, India (Fig. 1.7). Five of the ten top producers are in Asia and three are in Africa. Altogether, about 64% of the world's inland capture is accounted for by the top ten producers.




## 1.8 Geographical Distribution of Inland Capture




The continental shares of inland capture do not relate closely to the relative amounts of land and water available. For example, Asia produces nearly 64% of inland capture, but has only a 20% share of the total continental area (Fig. 1.8), a 23% share of swamps, marshes and other wetlands, a 7% share of lake area (Fig. 1.9 see following page), and an intermediate index of river density (Fig. 1.10 see following page). However, it does have a relatively large number of reservoirs (Fig. 1.10). There are a variety of factors involved: The apparent disproportionate share of inland capture in Asia is largely due to the heavy exploitation of virtually all of the available water surface and the widespread use of fishery enhancements, mainly stocking, to increase food fishery yields. In this way the Asian achievements provide an indication of the extent to which inland fisheries can be intensified through supplementation. Additionally, many fisheries probably produce relatively high yields because of heavy nutrient inputs from human settlements around lakes and from soil

erosion. Limited data suggest that in China eutrophication of lakes and reservoirs is proceeding at a rapid rate with more than one-half those surveyed classed as eutrophic based on 1987-1990 data (He, 1987; Jin, 1994). Much of the water surface in North America and the former USSR is in cooler regions. Further, in contrast to Asia, in much of North America inland fishery resources are managed mainly to produce game fish, not the food fish capture that is reported herein. In Europe inland fishery resources in rivers and small lakes and reservoirs have been managed to produce game fish, but at the same time management of many of the large lakes and reservoirs is aimed at commercial species. Another part of the differences can be explained by cultural attitudes towards inland fishes. In South America only a relatively few species of large-sized inland fishes are appreciated on urban markets.

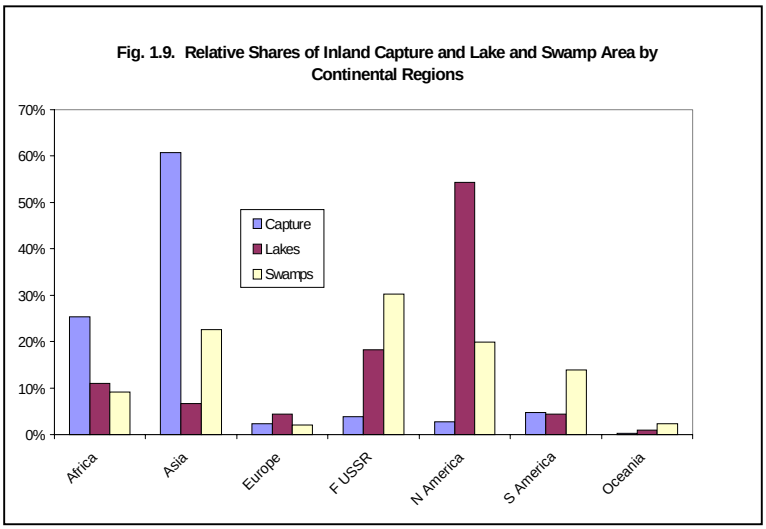



**Fig. 1.9. Relative Shares of Inland Capture and Lake and Swamp Area by Continental Regions**

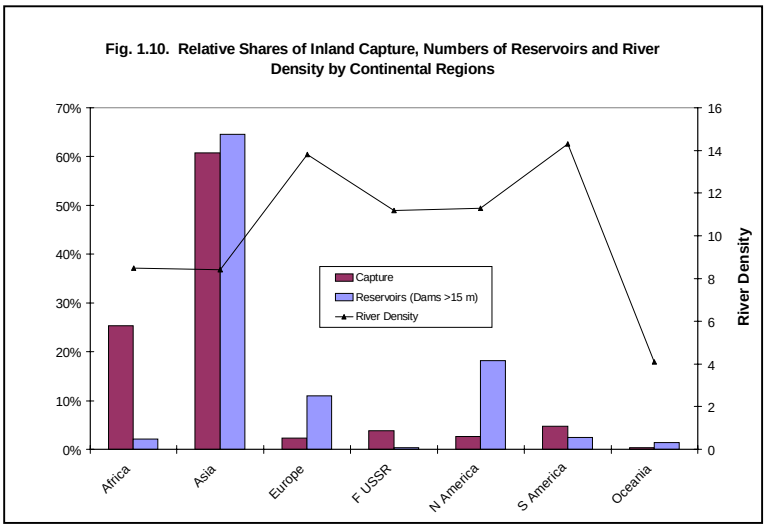



**Fig. 1.10. Relative Shares of Inland Capture, Numbers of Reservoirs and River Density by Continental Regions**

# 2. TRENDS IN INLAND CAPTURE

## 2.1 Introduction

In the following sections fourteen years (1984-1997) of inland capture data[4], where available, are plotted for each country by continental region and by sub-region.

The statistical trends exhibited by each country's data were calculated as part of the output of Fishstat Plus (Shatz, 1998) and these are commented upon to aid interpretation of the plots.

The sub-regional groupings usually follow those of the last review (FAO, Inland Water Resources and Aquaculture Service, Fishery Resources Division, 1995), except for Latin America and the Former USSR countries For the latter region, catch by country was available only from 1988 onward. For some other States, because of political changes, data are for less than 14 years.

The capture data by country within each sub-region were sorted on 1997, the most recent year, and the plots were then made in descending order. In order to avoid cluttered graphics, usually no more than 6 countries were plotted at one time. The data tables corresponding to the plots are in Annex 1.

## 2.2 Africa

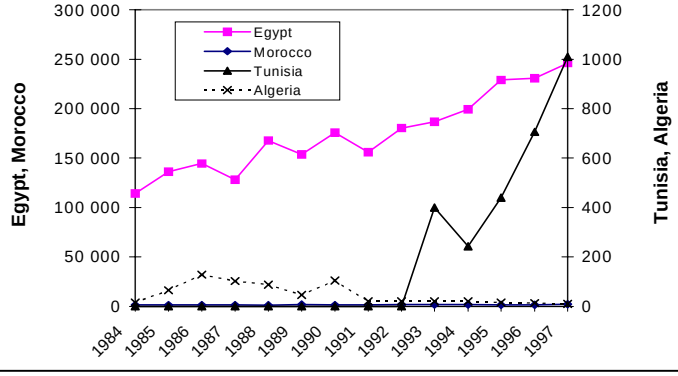
The overall 14-year trend for inland capture in this continental region is positive with an average annual increase of about 37 000 t. In overview, the 35 countries that exhibit either positive or stable trends account for 93% of the continental inland capture and the remaining 10 countries show negative 14-year trends.

### 2.2.1 Africa North of the Sahara

Egypt is the most important producer in this Sub-Region.

Of the four countries in this sub-region, Egypt, Tunisia and Morocco exhibit a positive trend and Algeria is negative (Fig. 2.1).

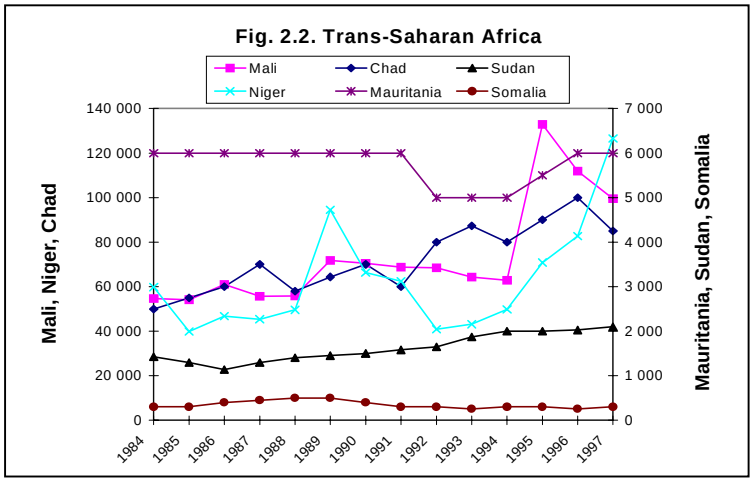
**Fig. 2.1. Africa North of the Sahara**




[4] Source: FAO Fishery Data, Information and Statistics Unit and www.Fao.org/WAICENT/FAOINFO/FISHERY/statist/statist.htm

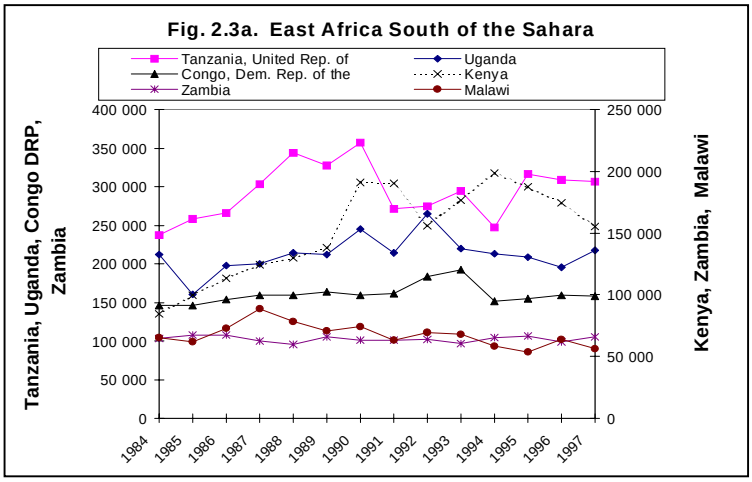
## 2.2.2 Trans-Saharan Africa

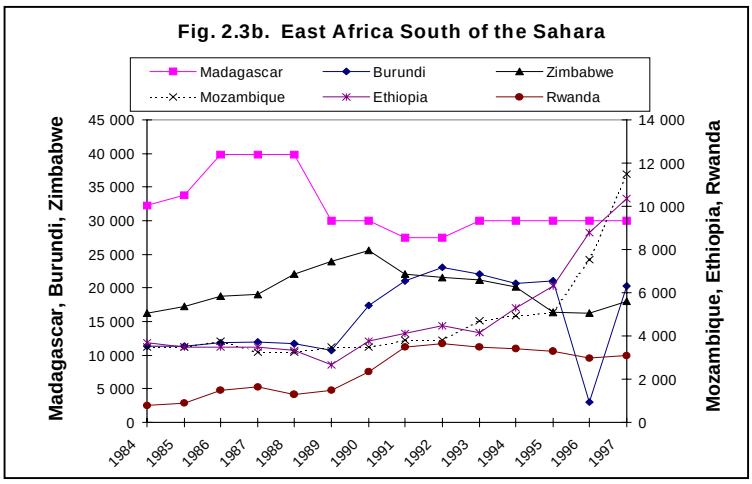
Mauritania and Somalia, relatively minor producers in this sub-region, have negative trends and the other four countries are positive. (Fig. 2.2)

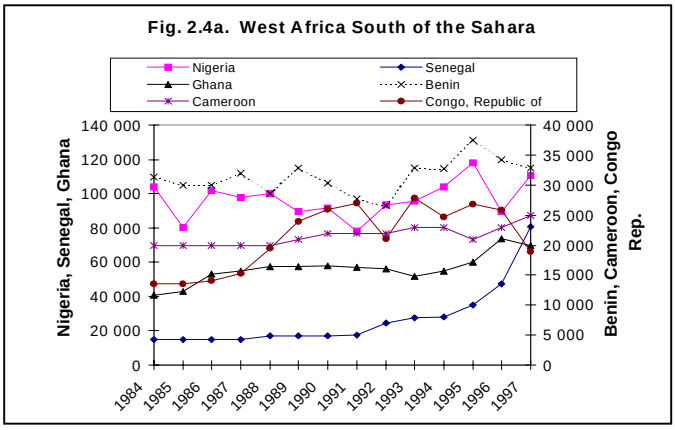


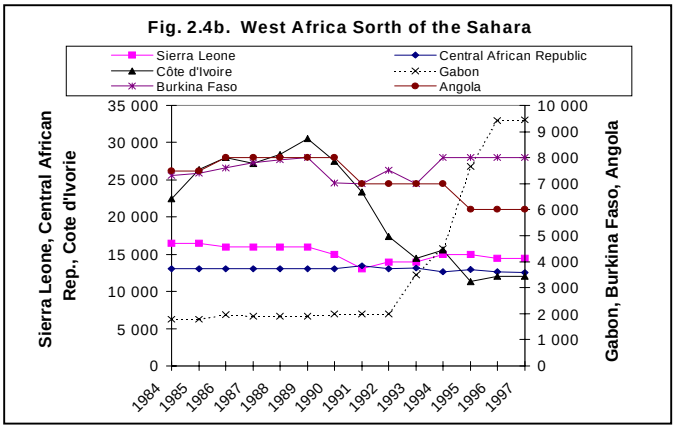

## 2.2.3 East Africa South of the Sahara

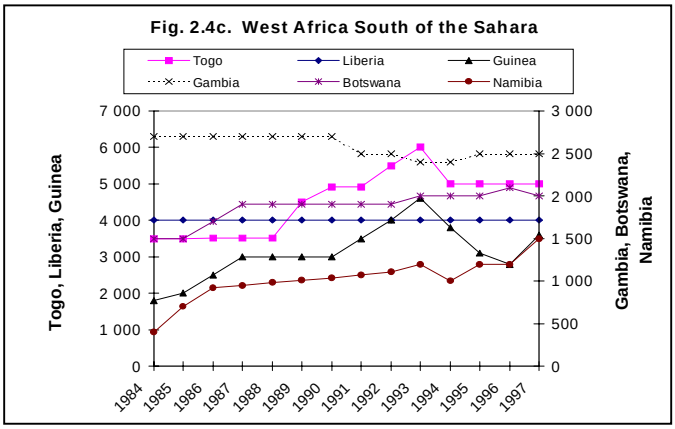
Tanzania, with important fisheries in two of Africa's major lakes, Victoria and Tanganyika, is, by far, the most important country for inland capture in Africa and the trend is positive. The trend is positive for Kenya, another important producer Africa-wide, as is the case for the other countries of the sub-region with the exception of Zimbabwe and Zambia that are stable and Malawi and Madagascar whose trends are negative. (Figs. 2.3a and 2.3b).

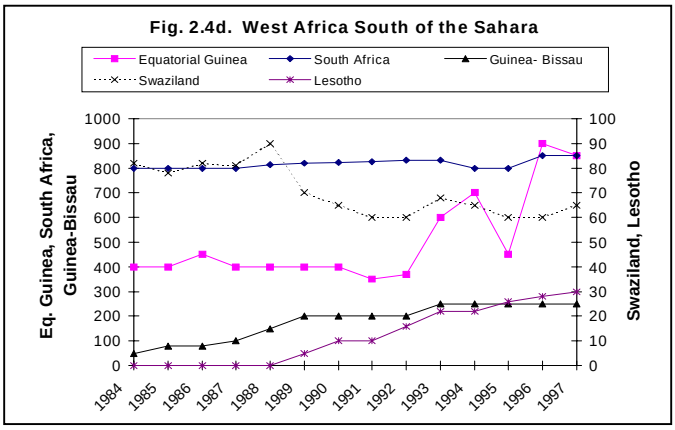





## 2.2.4 West Africa South of the Sahara

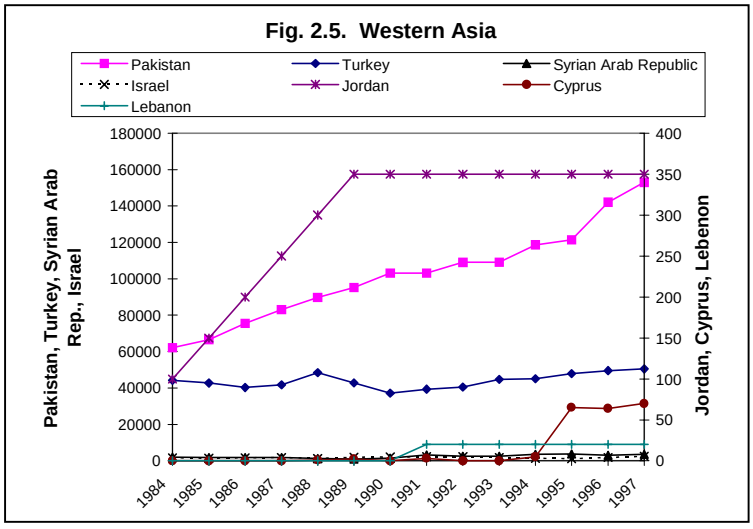
Nigeria, Senegal and Ghana are the most important inland capture countries in this sub-region, all with positive trends. Countries having negative trends are: Angola, Cote d'Ivorie, Gambia, Sierra Leone and Swaziland. The remainder are positive or stable (Figs. 2.4a to 2.4d).

## 2.3 Asia

Asia has a relatively positive trend and the annual average increase in capture has been about 137 000 t over the 14-year period. Recent years show a trend for a more rapid increase. In overview, 22 of 31 countries exhibit positive 14-year trends and these countries account for 92% of the total inland capture from the sub-region.

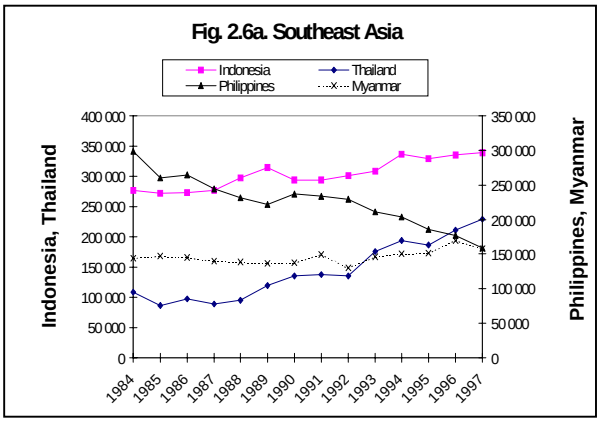
### 2.3.1 Western Asia

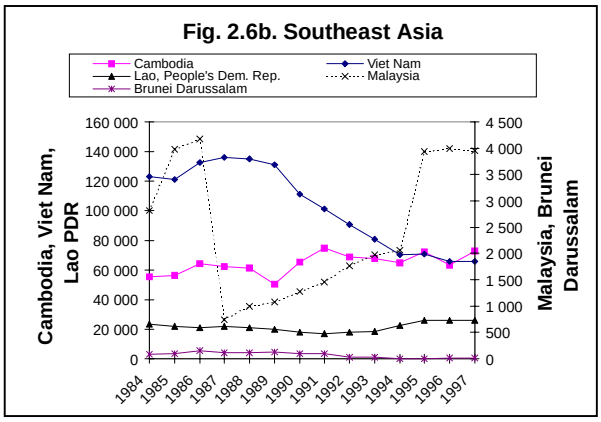
The most important producer is Pakistan (Fig. 2.5). All of the countries in this Sub-Region exhibit a trend for increasing inland capture.

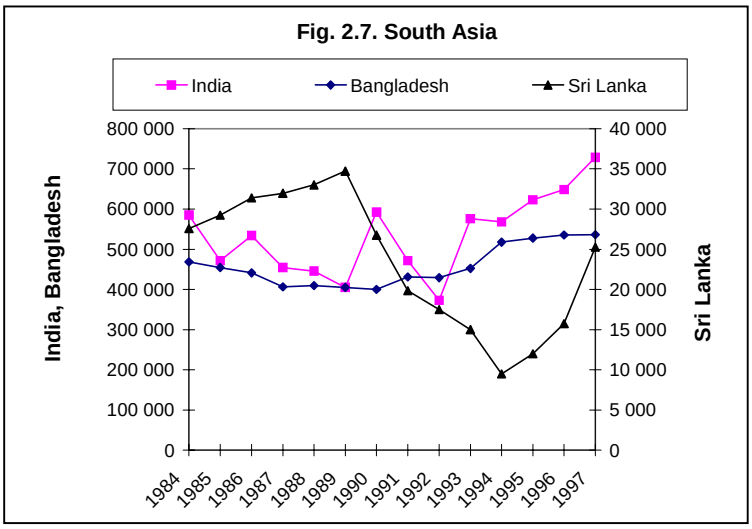



### 2.3.2 Southeast Asia

Indonesia and Thailand are the most important inland capture countries in this sub-region and the sub-region is among the most important world wide for inland fisheries (Figs. 2.6a and 2.6b). All but three countries, Philippines, Viet Nam and Brunei Darussalam, show a trend of increasing inland capture.

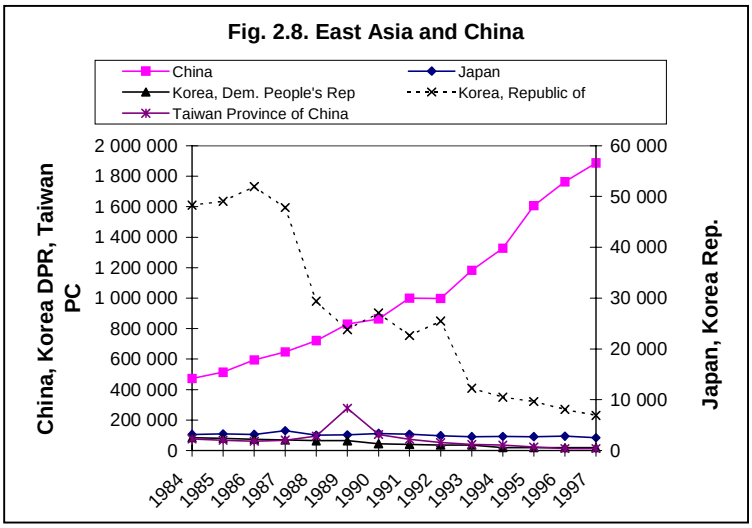





## 2.3.3 South Asia

The three countries of this Sub-Region account for more than 1.2 million t (Fig. 2.7). Capture from India and Bangladesh is on an increasing trend, but Sri Lanka is on a trend for decrease.

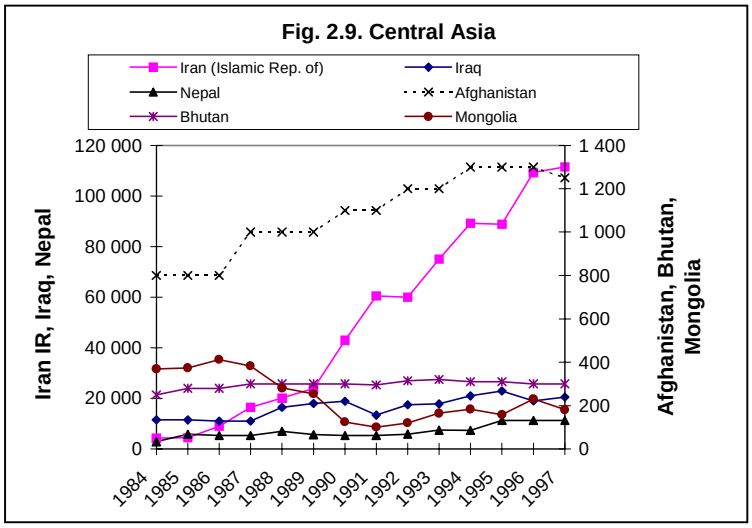



## 2.3.4 East Asia and China

As has been pointed out in Section 1, China is the top producing country in inland capture world wide and the trend is for a considerable annual increase in recent years (Fig 2.8). In contrast, capture is on a decreasing trend in Japan, the Democratic People's Republic of Korea, the Republic of Korea and the Taiwan Province of China.

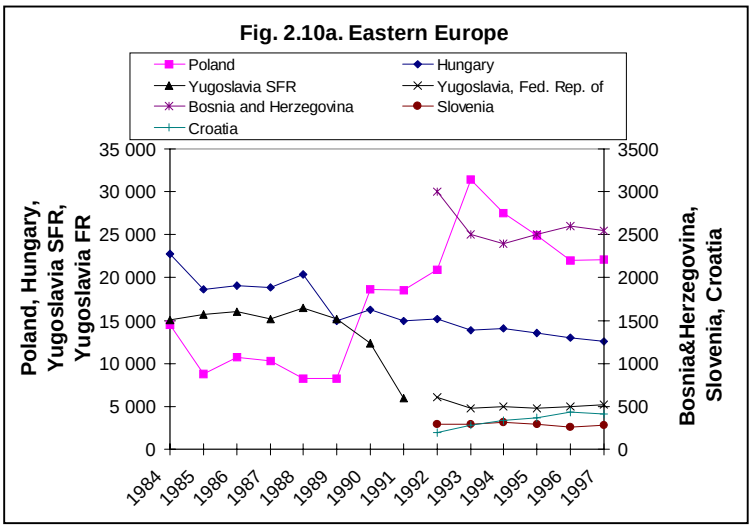
### 2.3.5 Central Asia

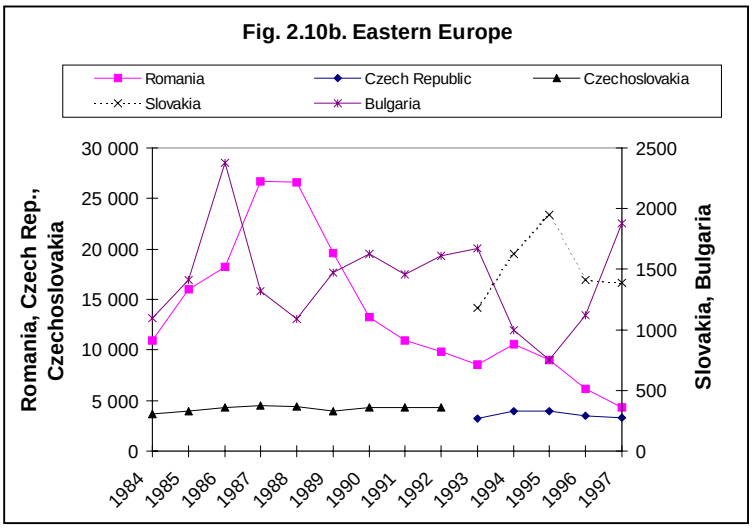
Iran is, by far, the most important inland capture country in this sub-region and increases in capture have been significant (Fig. 2.9). All the countries exhibit positive trends, except Mongolia, that shows a negative trend.




## 2.4 Europe

The overall 14-year trend for this continental region is very slightly negative with an annual average decrease of about 2 000 t. In overview, those countries with positive 14-year trends, 11 among 27, account for only 43% of the inland capture.

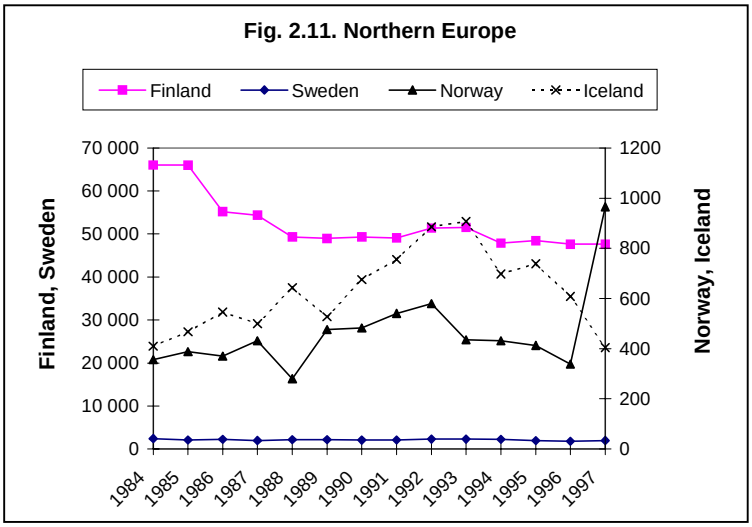



### 2.4.1 Eastern Europe

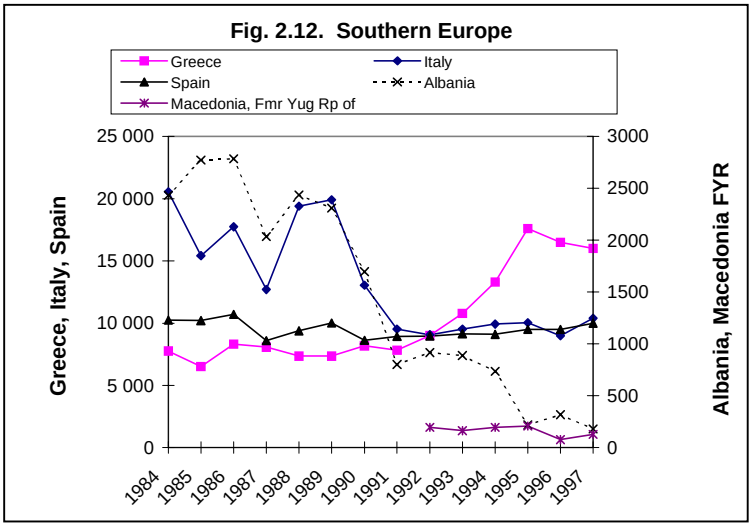
The 14-year trend for Poland, the most important producer in the sub-region, is positive while Hungary, Romania and Bulgaria are negative. (Figs. 2.10a and b). Because of political changes, trends for a number of countries are less than 14 years. Catch in the Yugoslavia SFR was relatively stable from 1984 to 1990 and declined significantly in 1991. Capture from the Federal Republic of Yugoslavia has been fairly stable since 1992 as has been the situation in the Czech Republic since 1993.

Croatia and Slovakia are positive while the other countries, Bosnia and Herzegovina and Slovenia, have been negative for the relatively short span of years of available data.




## 2.4.2 Northern Europe

Finland is the most important country for inland capture in this Sub-Region and Finland's capture trend is slightly negative as is Sweden's (Fig. 2.11). Positive trends are shown by Iceland and Norway.

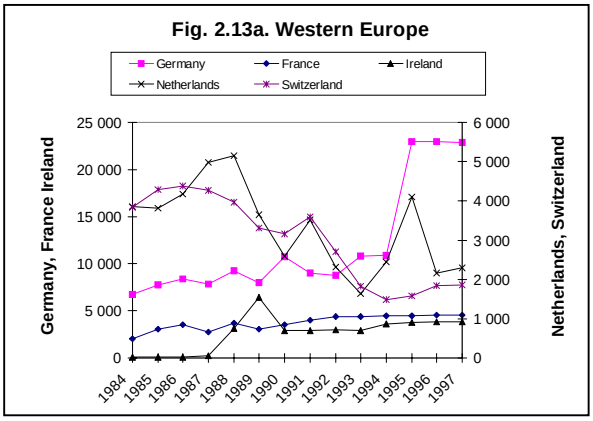


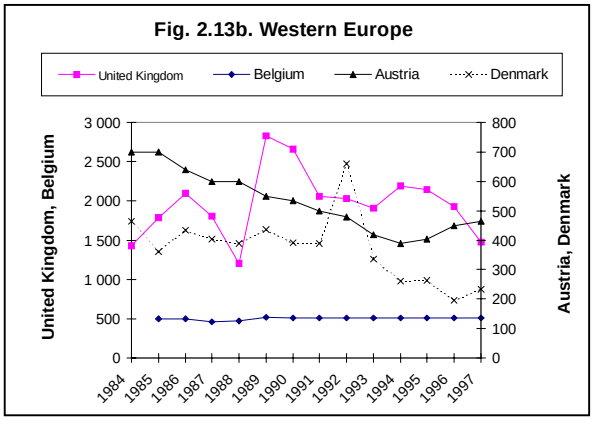

## 2.4.3 Southern Europe

Greece is the largest producer and the trend is positive (Figure 2.12). Spain, Italy and Albania exhibit negative trends. There are only five years of data for Macedonia and the trend there is negative, too.

## 2.4.4 Western Europe

In this Sub-Region the three largest producers, Germany, France and Ireland (Fig. 2.13a), show positive trends as do the United Kingdom and Belgium (Fig. 2.13b) while the remaining countries are negative. The recent large increase shown by Germany is due to more complete recreational fishery statistics.



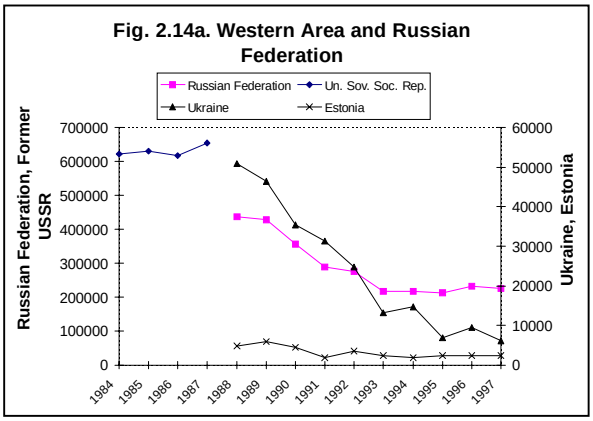



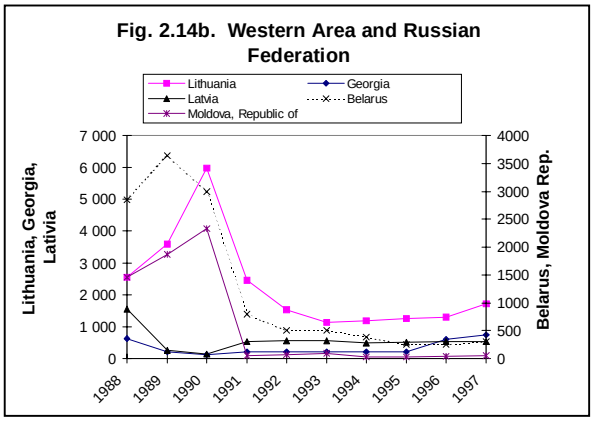
## 2.5 Former USSR

The overall 14-year trend for this Region is negative with an annual average rate of decrease of about 34 000 t. Unlike the other regions, capture data for the Former USSR group of countries are available only from 1988. Thus, the individual country trends are for 10 years. Only one country shows a positive trend in the entire Region, Georgia.

### 2.5.1 Western Area and Russian Federation

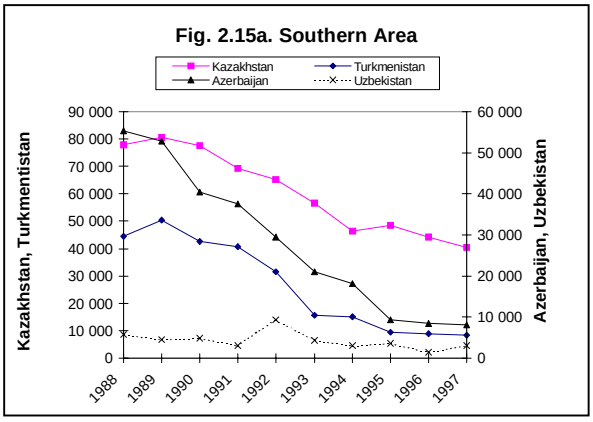
The Russian Federation is, by far, the most important producer in the entire Region. Steep declines have been experienced; however, there is a suggestion in the data for the Russian Federation, Estonia and Lithuania that a slight recovery is underway (Figs. 2.14a and 2.14b).

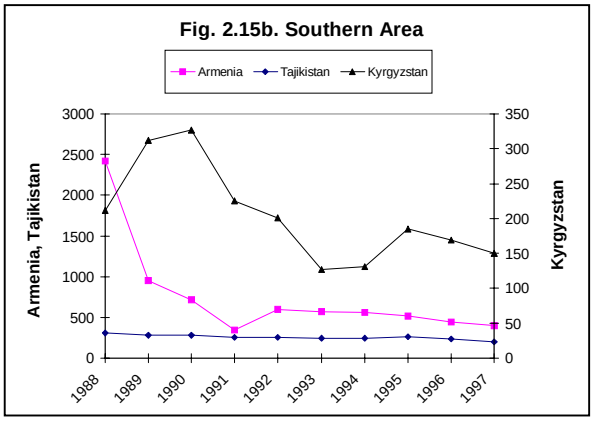



### 2.5.2 Southern Area

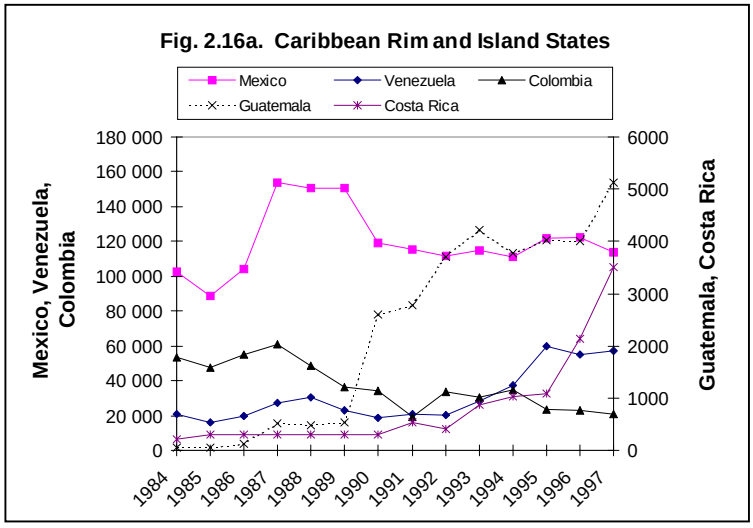
Kazakhstan is the most important inland capture country of the Sub-Region. Trends are negative for all of the countries (Figs. 2.15a and 2.15b).

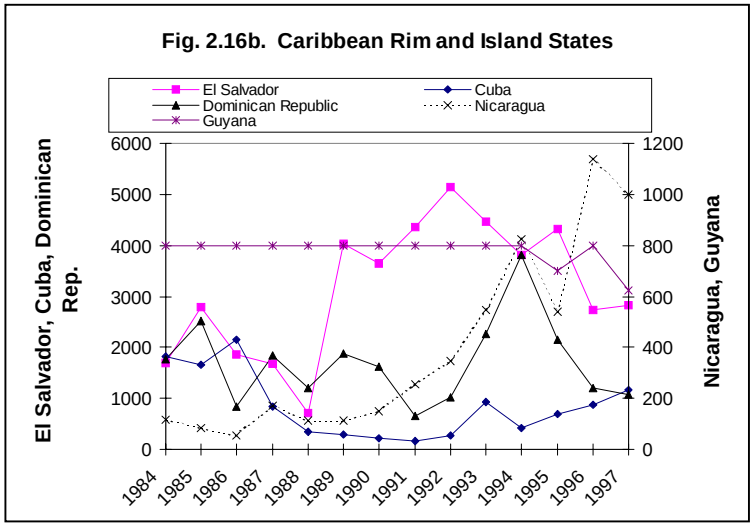


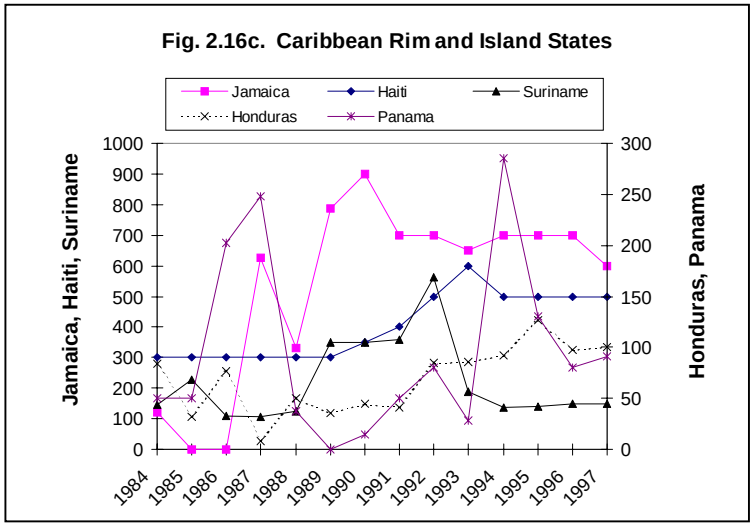



## 2.6 Latin America

The overall 14-year trend is positive with an modest average annual increase of about 3 000 t. In overview, the trend is positive or stable for 18 of the 22 countries and those 18 countries account for about 95% of the inland capture for the Region.



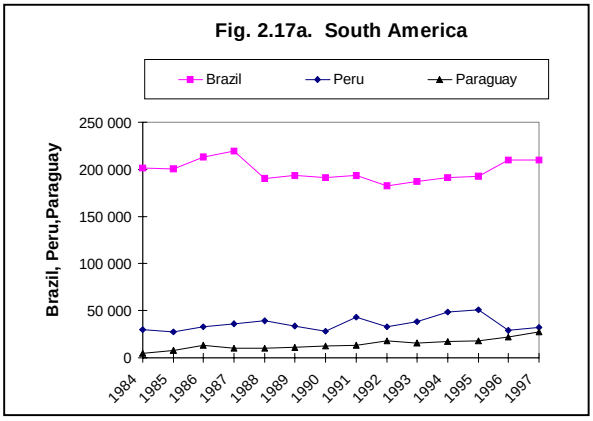



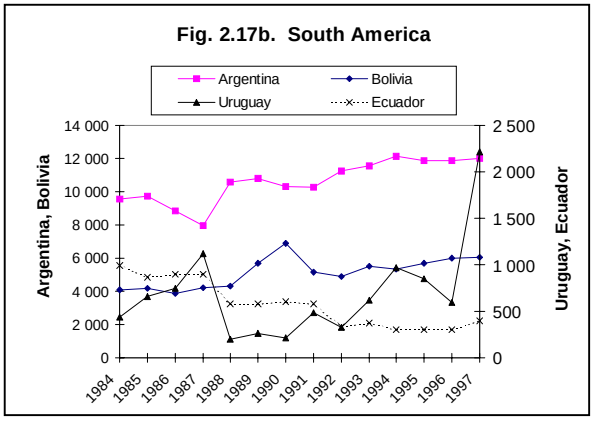

### 2.6.1 Caribbean Rim and Island States

Mexico is most prominent producer in the Sub-Region. In the entire Sub-Region the 14-year trends are positive for all countries (Figs. 2.16a, 2.16b and 2.16c) with the exception of Colombia, Cuba and Guyana, for the former, another important producer, there has been a substantial decrease. Although the overall trend for Cuba is negative, there have been increases in recent years. Nicaragua, Guatemala and Costa Rica have made impressive increases in inland capture.

### 2.6.2 South America

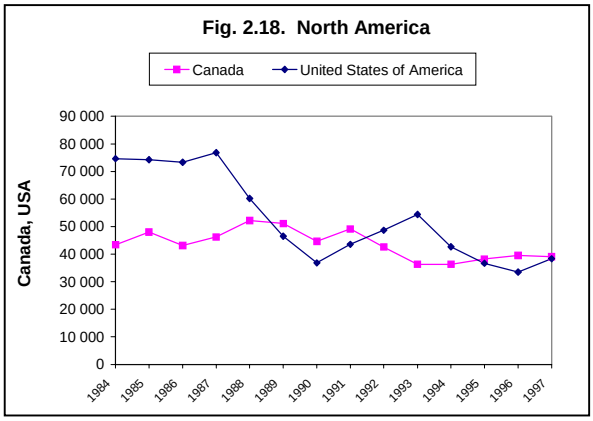
Brazil is the most important country in inland capture in the entire Region and the trend is stable (Fig 2.17a), while the remainder of the countries, except Ecuador, exhibit positive trends among which Paraguay has made the best gains (Figs. 2.17a and 2.17b).



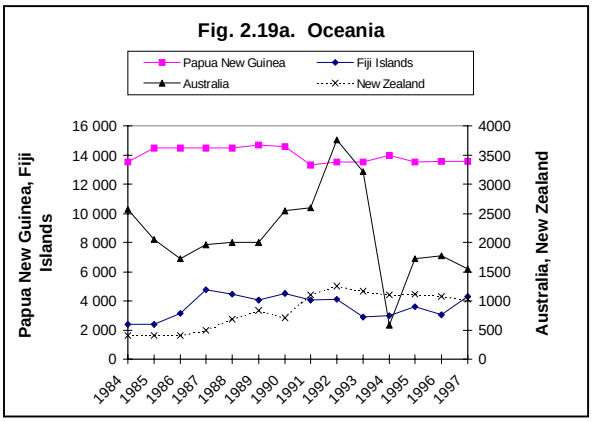

## 2.7 North America

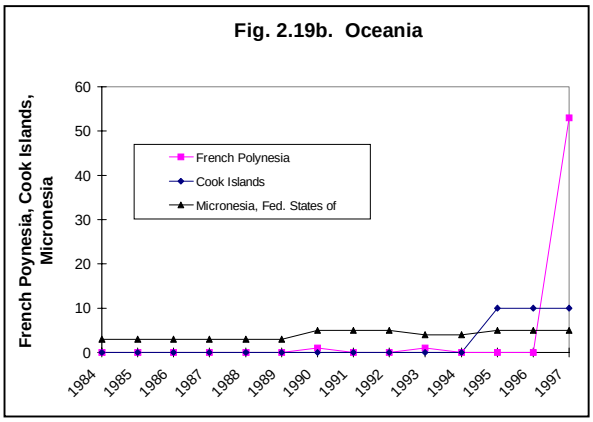
The continental trend for this Region is negative with an annual average rate of decrease of about 4 100 t. The trends for both Canada and for the USA are negative, but more marked in the latter (Fig. 2.18).




## 2.8 Oceania

The overall trend for this Region is stable. Of the 7 countries reporting inland capture in this Region, the trend is positive in 5, but they account for only 26% of the regional capture. Papua New Guinea is the most important and the trend is negative as is the case for Australia. (Figs. 2.19a and b).



# 3. GLOBAL ISSUES AND DIRECTIONS IN INLAND FISHERIES

## 3.1 Degradation of the Environment as the Main Issue

At the level of national fishery administrations there is varied, but ample evidence indicating that the single most important issue and preoccupation for the future of inland fisheries is the degradation of the environment and loss of fishery habitats. Restoration and rehabilitation figure prominently where the means and political will exist, indicating strong efforts to reverse degradation.

Indications of concern for the environment, mainly emanating from FAO Statutory Fishery Bodies, are set out below:

### Asia

A recent synthesis of country reports[5] prepared for the FAO Aquaculture and Inland Fisheries Committee (AIFIC) of the Asia and Pacific Fisheries Commission submitted by 10 countries, including the Region's largest inland producers, concludes that, although overfishing is common in many areas, environmental degradation of fish habitats is considered as a major problem.

### Africa

The theme selected for a recent Committee for the Inland Fisheries of Africa (CIFA) Symposium was "African Inland Fisheries, Aquaculture and the Environment" (Remane, 1997). This was the result of the perception of the CIFA Working Party on Pollution and Fisheries that environmental degradation in Africa was increasing.

At its tenth session (November, 1997) the CIFA identified six thematic areas of work for the next biennium. These were prioritised and the top one was environmental issues (FAO, 1998b).

### Latin America and the Caribbean

Among the main tendencies identified by the experts of the COPESCAL (Commission for the Inland Fisheries of Latin America and the Caribbean) Working Group on Fishery Resources at its 7th Session (May, 1997) was an increase in changes to and degradation of the environment and a preoccupation for the conservation of aquatic resources (FAO, 1997b).

The 8th Session of the COPESCAL (August, 1998) concluded that the most serious threat to inland fisheries is degradation of the environment and that environmental degradation already is limiting the development of aquaculture in some places. In this regard a serious problem at national levels is the lack of co-operation between institutions responsible for the environment and those responsible for inland fisheries and aquaculture (FAO, 1998a).

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[5] Petr, T. (MS). Synthesis of country reports on inland fisheries and aquaculture. Paper prepared for the Aquaculture and Inland Fisheries Committee of the Asia and Pacific Fisheries Commission. FAO, Rome (unpublished).

### Europe

"Rehabilitation of Rivers for Fish" (Cowx and Welcomme, 1998) arose from the work of the European Inland Fisheries Advisory Commission (EIFAC) Working Party on the Effects of Physical Modifications of the Aquatic Habitat on Fish Populations. The EIFAC ad-hoc Working Party on Methodologies for Rehabilitation of Lakes and Reservoirs has agreed to prepare a manual as a companion to the one on rivers. In general, Europe has made notable progress in leaning up its legacy of pollution from the industrial revolution and is now actively rehabilitating many watercourses.

### North America

Key agencies in the USA place heavy importance on restoration and rehabilitation. For example the US Fish and Wildlife Service has updated the national priorities of its Fisheries Resources Program to focus *inter alia* on recovering listed (i.e., listed as threatened and endangered) aquatic species, restoring fisheries and aquatic species, and restoring depleted fish populations to preclude listing. The first of three strategies of the U.S. National Marine Fisheries Service to implement the Recreational Fishery Resources Conservation Plan 1996-2001 is "Conserve, enhance and restore important fish stocks and their habitat".

## 3.2 Directions in Inland Fisheries

There are a number of clear trends that will affect the state and exploitation of inland fishery resources in the medium term that include:

- **Environment**
  Greater attention to stemming environmental degradation and reducing loss of habitats, partly based on an improving capability to link kinds, magnitudes and locations of degradations to their impacts on fishery resources and fisheries
- **Multipurpose conservation, rehabilitation and restoration**
  Greater influence of fishery interests in multipurpose conservation rehabilitation and restoration of aquatic systems and habitats
- **Enhancements**
  Use of enhancements, mainly stocking, to improve yields in food fisheries and expanded reliance on stocking for recreational fisheries

  Greater attention to enhancement effects on aquatic biodiversity as well as to the social and economic consequences of enhancements on fisher communities
- **Recreational Fisheries**
  Increasing importance of recreational fisheries among developing countries

  Increasing conflicts of allocation of resources between food and sport fisheries
- **Management**
  Better compliance with the FAO Code of Conduct for Responsible Fisheries and adaptation of the Code brought about by recognition of the of the special situations of inland capture and recreational fisheries relative to marine fisheries (FAO Fisheries Department, 1997)

  Increasing community level responsibility for management of inland fisheries, in general, and control of access in particular

More widespread use of river and lake basin frameworks for environmental and production management of fisheries

In the following sections the environment for inland fisheries, inland fishery enhancements, lake and river restoration and rehabilitation and recreational fisheries are examined in some detail.

## 3.3 The State of the Inland Water Environment

### 3.3.1 Inland Resources and the Environment

The state of inland fishery resources is very much reflected by the state of the terrestrial environment in general and by the state of the aquatic environment in particular. There are two major influences: climatic cycles and human-induced changes.

Climatic cycles, expressed as variations in rainfall, affect inland fishery resources by providing greater or lesser living space, more or less nutrients via inundation and rainfall runoff and higher or lower vulnerability to fishing due to concentration and dispersal. For example, some 57% of the large inland water body surface in Africa consists of systems with relatively widely varying surface areas both seasonally and inter-annually (Kapetsky, 1995). In these systems the availability of fishery resources for exploitation varies greatly and the impact on food security may be very serious in times of drought, or in times of especially high rainfall with extensive flooding.

Similarly, climatic cycles expressed as variations in temperature also affect inland resources. For example, temperature can be a lethal factor. At sub-lethal ranges it controls metabolic rates. It affects not only the rate of growth, but also fish behaviour. Temperature changes trigger fish movements and fish reproduction.

These climatic effects manifest themselves in the amount of fish available for capture. Therefore, long-term climatic changes, such as those brought on by global warming, are a concern for the future of inland fishery resources. In a more general way, all food producing sectors, including fisheries and aquaculture, are facing problems of environmental degradation and increasing land and water scarcity. The agricultural sector as a whole is facing increasing competition for water resources from industrialization and urbanization, and from growing requirements for safe drinking water supplies. These issues are particularly critical in many developing countries, given their high dependence on agriculture for food and income generation. Recent global assessments on freshwater resources and related international meetings including recent Sessions of the UN Commission on Sustainable Development, confirmed that some regions are or will be facing serious water shortages (United Nations (Economic and Social Council), 1997, 1998). One third of the world's population lives in countries experiencing moderate or high water stress. Demand by, and competition among various sectors for water - in terms of quantity and quality - will increase significantly, and politically difficult decisions on allocation and pricing of water uses, removal of subsidies, pollution control, and other measures have been suggested to avoid an imminent water crisis.

### 3.3.2 The State of the Inland Environment for Fisheries

Human-induced changes on inland fishery resources are manifold. In fact, the greatest overall threat to the sustainability of inland fishery resources is not over-exploitation, but degradation of the environment.

A number of measures of the state of the environment for inland fishery resources have been considered. Because this is a global review made largely from a continental perspective, only material that allows geographically broad comparisons has been selected.

**General Situation**

The Global Environmental Outlook (GEO-1) prepared by the UNEP is a snapshot of an ongoing environmental assessment process (UNEP, Global State of the Environment Report 1997). It provides two useful views of the environment from continental perspectives that can be interpreted for the state of inland fishery resources: relative importance given to environmental issues (Table 3.1) and environmental trends (Table 3.2). Seven measures are tabulated that have varying direct and indirect relevance and they are rated at four levels.

**Table 3.1. Regional concerns: Relative importance given to environmental issues by regions.**

| | Africa | Asia – Pacific | Europe & former USSR | Latin America & Caribbean | North America | West Asia |
|---|---|---|---|---|---|---|
| **Land: degradation** | 4 | 4 | 3 | 4 | 3 | 4 |
| **Forest: loss, degradation** | 4 | 4 | 3 | 4 | 2 | 2 |
| **Biodiversity: loss, habitat fragmentation** | 3 | 4 | 4 | 3 | 3 | 3 |
| **Fresh water: access, pollution** | 4 | 4 | 4 | 3 | 4 | 4 |
| **Marine and coastal zones: degradation** | 3 | 4 | 4 | 3 | 3 | 4 |
| **Atmosphere: pollution** | 3 | 4 | 4 | 4 | 4 | 3 |
| **Urban and industrial: contamination, waste** | 3 | 4 | 4 | 4 | 4 | 4 |

4) Critically important; 3) Important; 2) Lower priority; 1) Negligible

**Table 3.2. Regional environmental trends.**

| | Africa | Asia – Pacific | Europe &former USSR | Latin America & Caribbean | North America | West Asia |
|---|---|---|---|---|---|---|
| **Land: degradation** | 4 | 4 | 3 | 4 | 2 | 4 |
| **Forest: loss, degradation** | 4 | 4 | 3 | 4 | 3 | 4 |
| **Biodiversity: loss, habitat fragmentation** | 4 | 4 | 4 | 4 | 3 | 4 |
| **Fresh water: access, pollution** | 4 | 4 | 3 | 4 | 3 | 4 |
| **Marine and coastal zones: degradation** | 3 | 4 | 4 | 4 | 3 | 4 |
| **Atmosphere: pollution** | 3 | 4 | 3 | 4 | 3 | 3 |
| **Urban and industrial: contamination, waste** | 3 | 4 | 3 | 4 | 3 | 4 |

4) Increasing 3) Remaining relatively stable 2) Decreasing 1) Not applicable, not known

*With regard to relative importance of the issues* (Table 3.1) across the continents, freshwater access and pollution along with urban and industrial contamination and waste are foremost. With regard to the continental regions, all of the issues are critically important in the Asia-Pacific and 5 of 7 are in this category in Europe and the former USSR countries.

*With regard to trends* (Table 3.2), the general situation that prevails is not encouraging when interpreted in terms of the present state and near-future outlook for inland aquatic resources. The most frequently occurring problem is biodiversity loss and habitat fragmentation, but scarcity and pollution of freshwater; land degradation; forest loss and degradation all are increasing in Africa, Asia-Pacific, Latin America and the Caribbean and West Asia. In Europe and the former USSR these are remaining relatively stable, except for biodiversity loss and habitat degradation, which are increasing. In North America land degradation is decreasing while the others are remaining relatively stable.

Fresh water is among the four key priority areas that emerge from the GEO-1 report for immediate, enhanced and concerted action by the international community, if the world is to reverse negative environmental trends.

### Watershed Vulnerability

Another measure of the state of the aquatic environment for fisheries is provided by the analysis of 145 large watersheds around the world that account for 55% of the land surface, not including Antarctica (Revenga, et al. 1998). The analysis focuses primarily on watersheds as ecological units and on the risks of degradation from human activities that may undermine their ability to provide ecological services and maintain intact the biodiversity within them.

The analysis showed that watersheds ranking highest in biological value are also generally the most degraded. Biological value was based on the number of fish species and fish endemics, and the number of areas with endemic birds.

Stresses were found to be especially severe in watersheds already substantially modified or degraded. In particular, India, China and Southeast Asia stood out as places where pressures on watersheds are intensifying. This is of concern because, as was shown above (Section 1), these correspond to the most important areas of inland fish production globally. Other major watersheds that are relatively less degraded, such as the Amazon and the Congo, nonetheless are beginning to experience rapid change.

**Freshwater Biodiversity**

World wide, among 151 river basins, thirty have been identified that support high aquatic biodiversity on the basis of high fish family richness and high vulnerability to future pressures (World Conservation Monitoring Centre, 1998). Vulnerability was based on a low score for wilderness and a high water resource vulnerability index. Basically, these are high-level measures of the state of catchments and the pressures exerted on them.

Of the 30, 39% (by total area) are in Africa, 35% in Asia and 26% in Latin America (Table 3.3; see following page) Using these biodiversity-vulnerability measures, the most stressed catchments are to be found in South Asia, the Middle East and western and north-central Europe. The least stressed are those in the north-western part of North America.

**Conservation Status of the World's Fish Fauna**

Looking at trends in freshwater fish faunas from different parts of the world indicates that most fauna are in serious decline and in need of immediate protection (Leidy and Moyle, 1998). In freshwater systems, among those that are usually heavily fished, fish losses appear to be highest in (1) industrialised countries, (2) in regions with arid or Mediterranean climates, (3) in tropical regions with large human populations and, (4) in big rivers.

In Canada, the USA and Mexico the nature of the threats to 364 fish taxa that have been classified as endangered, threatened, or of special concern has been quantified in the following way (Williams, 1997):

- 93% habitat loss
- 41% exotic introductions
- 39% restricted range
- 3.3% overuse (overfishing)
- 1.4% disease

The total is greater than 100% because a taxon may suffer from more than one kind of threat. Therefore, the threats are not additive.

**Table 3.3. Thirty high priority river basins (modified from WCMC, 1998)**

| **Asia** | **Africa** |
|---|---|
| Ca | Gambia |
| Cauvery | Niger |
| Chao Phraya | Nile |
| Ganges-Godavari | Senegal |
| Indus | Volta |
| Irrawaddy | **South America** |
| Krishna | Magdalena |
| Ma | Parana |
| Mahanadi | Parnaiba |
| Mekong | Sao Francisco |
| Narmada | Uruguay |
| Pahang | |
| Penner | |
| Perak | |
| Salween | |
| Sittang | |
| Song Hong (Red) | |
| Tapti | |
| Tembesi-Hari | |

**Introductions**
Human-induced changes are reflected in the composition of the inland fish fauna to the point that introduced species figure as relatively important in the freshwater capture. For example, Nile tilapia (and other tilapias) are important in Asia, Latin America and Oceania. Common carp are important in Europe, Latin America and North America. According to the FAO Data Base on Introductions of Aquatic Species[6], common carp, rainbow trout, Mozambique tilapia, grass carp, and Nile tilapia are the most frequently recorded introductions (Bartley et al., 1995). In the recreational sector, on average, non-native sport fish fishes provided 38% of recreational fishery use in the USA (Horak, 1995).

## 3.4 Overview of Inland Fishery Enhancements from a Global Perspective

### 3.4.1 Introduction

Most inland capture fisheries that depend only on natural production are exploited above or close to their sustainable maxima and as a result global inland capture fisheries production is increasing at a slow rate (Fig. 1.5). Increasing pressure on the fishery resources, environmental degradation of aquatic habitats and poor fisheries management have contributed to this situation. Conventional fisheries management measures such as regulation of minimum mesh sizes, closed areas and closed seasons are used to counteract this situation, but these measures can be difficult to enforce and do not always offer the possibility to increase or maintain production levels in situations of high fishing pressure or in degraded environments. In such cases, other techniques are used. These techniques can be collectively termed as enhancements and include various possibilities to intensify fishery production. These include (after Welcomme and Bartley, 1998):

- **Introduction of new species** to exploit under-utilised parts of the food chain or habitats not colonised by the resident fauna;
- **Stocking** natural waters to improve recruitment, bias fish assemblage structure to favoured species or maintain productive species that would not breed naturally in the system;
- **Fertilisation** to raise the general level of productivity and hence growth of the fish;
- **Engineering of the environment** to improve levels of reproduction, shelter, food resources and vital habitat; This also includes the establishment of sanctuaries to protect endangered fish species, to use the protected stock for enhancement and to protect the genetic purity of selected fish species;
- **Elimination of unwanted species** that either compete with or predate upon target species.
- **Constituting an artificial fauna** of selected species to increase the degree of control and the yield from the system;
- **Modification of water bodies** to cut off bays and arms to serve for extensive and intensive fish ponds to increase control and nutrient flows;
- **Introduction of cage culture** and parallel intensification of effort of the capture fishery;

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[6] FAO Data Base on Introduced Species;
http://www.fao.org/WAICENT/FAOINFO/FISHERY/statist/fisoft/dias/index.htm

- **Aquaculture** through management of the whole system as an intensive fish pond;
- **Genetic modification** to increase growth, production, disease resistance and thermal tolerance of the stocked or cultured material.

Inland fishery enhancements are becoming a central theme in inland waters and are widely applied nowadays. The exact contribution of enhancements to the total inland capture fisheries production is difficult to estimate, but it is believed that many inland fisheries are supported by various forms of enhancement, often combined with conventional fisheries management practises.

FAO has been increasingly involved with the promotion of inland fishery enhancements; however, this is the first attempt to globally and comprehensively characterise inland fishery enhancements by taking into account enhancement types, their geographic distribution and the species employed. The results are summarised in the following sections.

Of the first four enhancement types mentioned above (i.e. introductions, stocking, engineering of the environment and fertilisation), introductions and stocking are the most commonly applied (Table 3.4). Introductions and stocking programmes are mostly applied to lakes, reservoirs and rivers and less information is available on the enhancements of fisheries in other kinds of water bodies, although specific examples exist. There exist also a large number of small water bodies such as village ponds, and small irrigation tanks. that have potential for enhancement. Stocking of fish in these smaller water bodies has been generally more successful because these are easier to manage, do not require large amounts of stocking material and are often more productive. In contrast, introductions of new species with the aim to establish self-reproducing populations (auto-stocking) have been more effective to enhance fisheries in the larger water bodies.

**Table 3.4. Available information on enhancements in Aquatic Sciences and Fisheries Abstracts**

| Enhancement Type | No. of references in ASFA |
|---|---|
| Introductions | 1355 |
| Stocking | 1274 |
| Environmental Engineering | 404 |
| Fertilisation | 21 |

Most enhancements are carried out to produce food and generate income, (fisheries production) but also for the benefit of recreational fisheries, to restore collapsed fisheries (due to over-fishing/environmental degradation) and to control pests (aquatic weeds, mosquitoes).

### 3.4.2 World Perspective on Established Introductions

The most widespread introduced species that have established self-reproducing populations in open waters and globally contribute significantly to food production are Mozambique tilapia, common carp, rainbow trout, Nile tilapia and brook trout (Table 3.5). Mosquito fish and guppy have been widely introduced for mosquito control and grass carp for the control of aquatic weeds. The goldfish has been mainly introduced for ornamental reasons. The distribution of introduced species that established in the wild is given in Figure 3.1.

**Table 3.5. Introduced/translocated species that have established self-reproducing populations in the wild**

| Common name | Scientific Name | No. of Countries | Main Continents |
|---|---|---|---|
| Mozambique tilapia | *Oreochromis mossambicus* | 59 | World wide |
| Common carp | *Cyprinus carpio* | 56 | World wide |
| Mosquitofish | *Gambusia affinis* | 41 | Oceania, Worlwide |
| Rainbow trout | *Oncorhynchus mykiss* | 41 | World wide, North America (translocated) |
| Goldfish | *Carassius auratus* | 39 | Europe, Latin America, North America |
| Largemouth bass | *Micropterus salmoides* | 35 | Africa, Europe, Latin America, North America |
| Nile tilapia | *Oreochromis niloticus* | 29 | Latin America, Asia, Africa |
| Guppy | *Poecilia reticulata* | 27 | Oceania, Asia, Africa, Latin America |
| Brook trout | *Salvelinus fontinalis* | 23 | Europe, Latin America, North America (translocated) |
| Brown bullhead | *Ameiurus nebulosus* | 21 | Europe, North America |
| Grass carp | *Ctenopharyngodon idella* | 20 | Europe, North America |
| Brown trout | *Salmo trutta* | 23 | Asia, Oceania |
| Silver carp | *Hypophtalmichthys molitrix* | 18 | Asia (India) |

(*Source*: FAO Database on Introductions of Aquatic Species (DIAS)).

## 3.4.3 World Perspective on Stocking

With regard to stocking, common carp, rainbow trout, Atlantic salmon and brook/sea trout are relatively widespread as can be seen in Table 3.6. Most of the species in the table are stocked for food production, income generation and for recreational fisheries. Common carp and rainbow trout are also important introduced species that successfully established, but these species are also supported by hatchery production. The geographical distribution of stocked freshwater species is given in Figure 3.2. This figure is primary based on hatchery production data provided to FAO by it's member countries, but for some countries with incomplete hatchery production data species have been added on the basis of scientific literature. The USA, Poland, Australia, Finland, France, Iran and Mexico report the highest number of species.

**Table 3.6. Most commonly stocked freshwater species**

| Common Name | Scientific Name | No. of Countries | Main Continents |
|---|---|---|---|
| Common carp | Cyprinus carpio | 44 | Worldwide |
| Rainbow trout | *Oncorhynchus mykiss* | 39 | Europe, North America, South America, Africa, Asia |
| Atlantic salmon | *Salmo salar* | 24 | Europe, North America |
| Brook trout/sea trout | *Salmo trutta* | 23 | Europe, North America |
| Nile tilapia | *Oreochromis niloticus* | 19 | Africa, Latin America, North America |
| Pike | *Esox lucius* | 17 | Europe, North America |
| Grass carp | *Ctenopharyngodon idella* | 16 | North America, Asia |
| Silver carp | *Hypophthalmichthys molitrix* | 15 | Asia, Europe |
| Pikeperch | *Stizostedion lucioperca* | 14 | Europe North America, Asia |
| Mozambique tilapia | *Oreochromis mossambicus* | 10 | Africa, Asia, North America |

(*Source:* FAO Hatchery Production Database)).

The available information on stocking, introductions and translocations as found by an extensive search in the Aquatic Abstracts and Fisheries Sciences database shows that the highest numbers of references deal with North America, Europe and Russia (Figure 3.3). Various countries in Asia and Oceania (China, India, Australia, Thailand and Papua New Guinea) have a considerable information base. Published information in the ASFA database is relatively scarce for Africa and Latin America, however as described in the previous paragraphs, these continents do have fisheries that are supported by stocked and introduced species. It is important that the results of such stocking programmes and introductions are published as it forms the basis for further evaluation of these techniques.

In the following paragraphs, a brief overview is given for each region.

## 3.4.4 Asia and Oceania

A variety of species have been introduced to this region, mainly for the purpose of aquaculture. Many of these have established populations in open waters. Mozambique tilapia, common carp, rainbow trout and Chinese carps are important for commercial capture fisheries. For example, Mozambique tilapia established itself successfully in the larger reservoirs in Sri Lanka where it is now the main species contributing to the reservoir catch (de Silva 1988). This species also established itself successfully in many Indian reservoirs (Sugunan, 1995). Transloctions of species within the country have created new fisheries in China. Most recently icefish (*Neosalanx taihuensis* and *Protosanlanx hyalocranius*) was very successfully transplanted to various provinces of China. By 1997, the production reached 10 000 metric tons, of which transplanted icefish contributed as much as 8 000 metric tons (Miao pers.comm.). Translocations of indigenous species have also been one of the major measures for enhancement of inland water bodies in Australia, mainly for the purpose of recreational fisheries (Petr 1998). Introduction of Nile tilapia and common carp into larger reservoirs of the lower mekong countries (Laos, Cambodia, Vietnam and Thailand) were generally successful whereas non-indigenous Indian and Chinese carps generally failed to establish themselves (Bernascek, 1997). Common carp was however not successfully introduced in Indian reservoirs (Sugunan, 1997). Introduced *Tilapia rendalli* to the Sepik River, Papua New Guinea, is now established in this river system.

**Figure 3.1: Geographic distribution of the number of introduced freshwater species that are established in the wild** (*Source:* FAO Database on Introductions of Aquatic Species (DIAS))

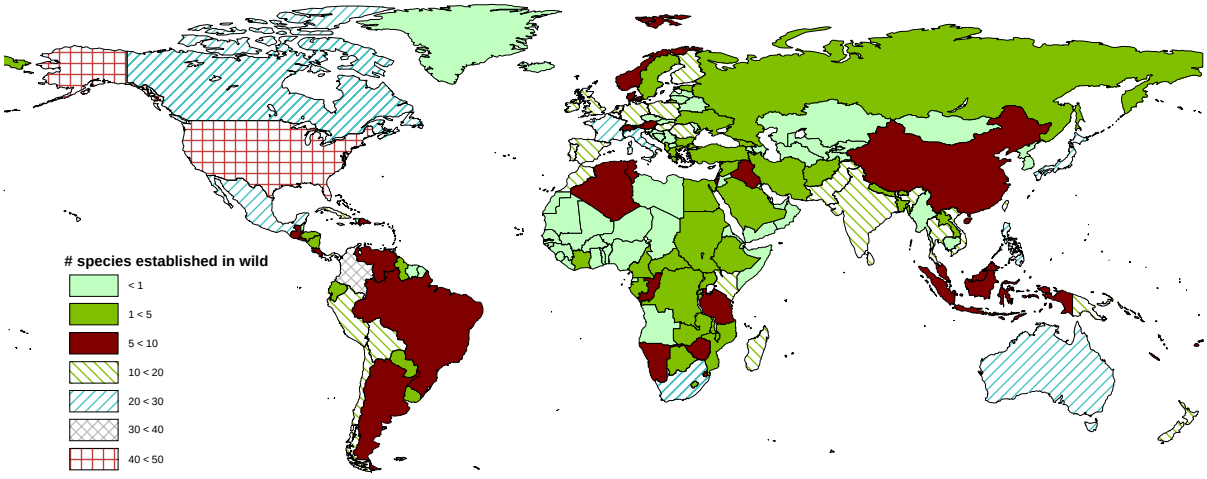



**Figure 3.2: Number of freshwater species reported to FAO as produced in hatcheries and released into the wild** (*Source:* FAO Hatchery Production Database)

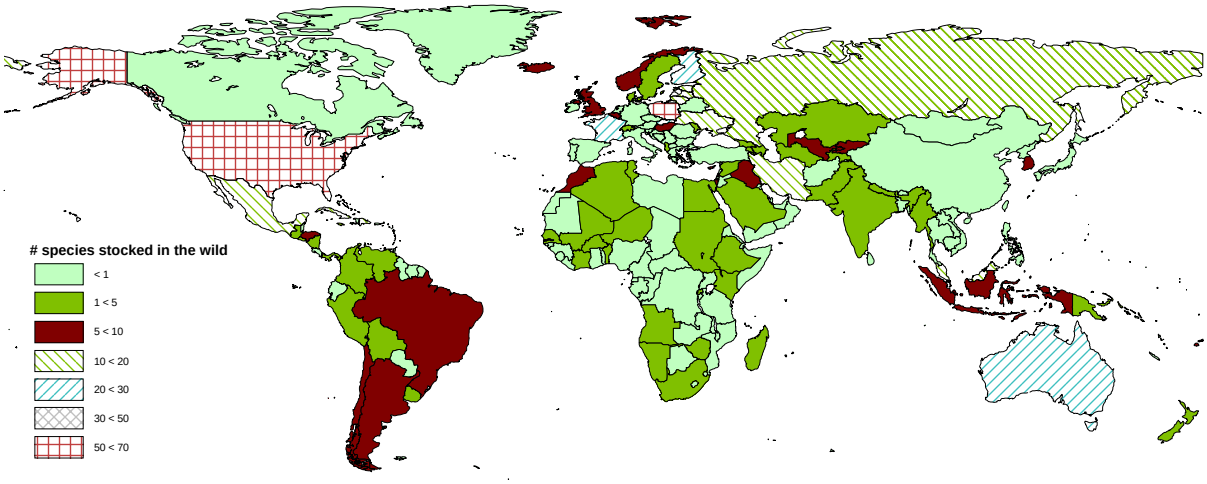
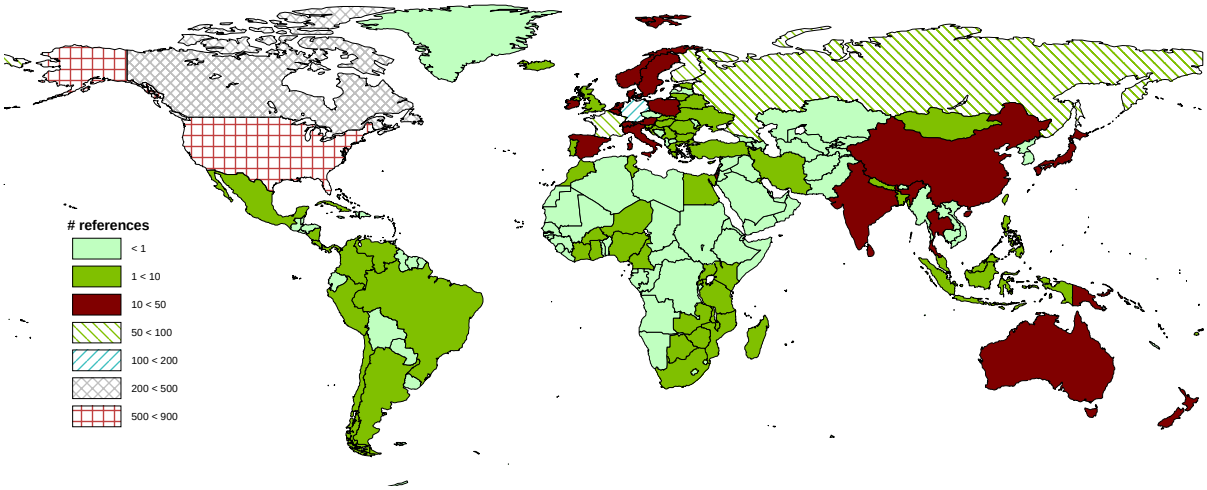



**Figure 3.3: number of ASFA references on introductions, translocations and stocking of inland waters** (*Source:* FAO Inland Fishery Enhancements Database)



Stocking has yielded better results in the smaller water bodies, though relatively large lakes and reservoirs are stocked successfully in China. Bighead carp and silver carp are the main species stocked in China (60-80% of the stocked species). Chinese carps, Indian carps, tilapias, common carp and rainbow trout are the most common species used for stocking in this region. Stocking of the indigenous species (silver perch, golden perch and Australian bass) are important for recreational fisheries in Australia. Practises of environmental engineering are not described frequently, but they do exist. Cage and pen culture are widespread in this region, notably in China, Indonesia and the Philippines. Other measures include screening of in- and outlets, protection and construction of spawning habitats, re-establishment of floodplain-river connections and the construction of brush parks.

### 3.4.5 Africa

The majority of countries in Africa report introductions. The introduction of the Nile perch (*Lates niloticus*) outside its original distribution area, has created a major commercial fishery with substantial economic and nutritional benefits (Reynolds and Greboval 1988) but at the same time it is held responsible for disruption of the Lake Victoria ecosystem. It has been a controversial introduction. A successful introduction has been that of the Lake Tanganyika Sardine (*Limnothrissa miodon*) into Lake Kariba, Cahora Bassa and Lake Kivu (Marshall, 1991; Lévêque, 1998; Spliethof *et al*. 1983) that has contributed significantly to fishery output.

Apart from these often referred to introductions, tilapias, common carp and rainbow trout have been distributed over this continent. Largemouth bass and sunfish have been introduced for recreational fisheries in respectively 11 and 6 African countries. Many species were introduced into Madagascar. Of the 23 species introduced to this country, 14 established in open waters where they contribute to subsistence, commercial and sport fisheries (Moreau, 1987).

Information on stocking practises in Africa is relatively scarce. Stocking of small man-made reservoirs in Zimbabwe, of floodplain pools in Nigeria and of seasonal small water bodies in Burkina Faso (<50 ha) is reported. Stocking of larger water bodies is reported for Lake Nasser and Lake Quarun in Egypt. Overall it can be concluded that stocking of open waters is not very common in Africa.

Other enhancements reported include the brush park fisheries in lagoons in Côte d'Ivoire and elsewhere in West Africa and hydraulic management in lagoons, but the information is very scarce.

### 3.4.6 Latin America

Tilapias have been widely introduced in this region and in many cases these species contribute significantly to fishery production (Juarez-Palacios and Olmos-Tomassini 1991). Self-reproducing populations of tilapias were formed in lakes and reservoirs in Colombia and contribute significantly to the total fish production in the country (Castillo Campo 1996). *T. rendalli* and *O. niloticus* form an important component of the fish catch in the reservoirs of northeast Brazil (Gurgel and Fernando 1994) and in Cuba they are the main species in culture-based fisheries (see section on stocking). Common carp is also relatively wide spread in this region though they did not successfully establish in Norteast Brazil (Gurgel and

Fernando 1994). Salmonids (pacific salmon, brook trout) have been introduced to Chile and Argentina.

Stocking is practised in various countries, notably in Cuba (tilapia and Chinese carps in reservoirs), Argentina and Chile (salmonids), Brazil (tilapias in Northeast Brazilian reservoirs) and recently in Mexico (tilapias, common and Chinese carps in reservoirs). Cage culture is practised in reservoirs in Argentina and Colombia and experimentally in some other countries in the region. Information on environmental engineering as a tool for fishery enhancement in this region is not available from the literature searches in ASFA.

### 3.4.7 North America

Numerous species were introduced to this continent and a considerable amount of lietarature is available (697 references in ASFA). These mainly deal with invasions and the related environmental effects of various accidentally introduced species such as Zebra mussel (*Dreissena polymorpha*), ruffe (*Gymnocephalus cernuus*) and sea lamprey (*Petromyzon marinus*) into the Great Lakes area. Information on intentional introductions involve those of various species to enhance recreational fisheries in small impoundments. For example, in California, 30 exotic species were introduced to enhance recreational fisheries of which black bass, catfish (*Ictalurus* spp.), sunfishes (*Lepomis* spp.) and striped bass (*Morone saxatalis*) contributed 42-77% to the angling catch in this State (Lee, 1995). In Florida where butterfly peacock bass (*Cichla ocellaris*) was introduced into 11 coastal canals, where it has established self-reproducing populations and it contributes significantly to the sports fisheries in the area, without significant negative impacts (Schafland, 1995).

In the Canadian Province Ontario and in Michigan and New York State (USA), introductions of Atlantic salmon (*S. salar*) into Lake Ontario were done to restore the population (Jones and Stanfield 1993). Pacific salmon (*Oncorhynchus* spp.) was introduced in the tributary streams of Lake Ontario (Rand *et al*. 1992) and the introduction of white perch *(Morone americana*) was successful in that it has become a major commercial species (Haynes *et al.* 1982). Small numbers of pink salmon (*O. gorbusha*) were released into Lake Superior in 1956 and have established a population of significance (Bagdovitz *et al*., 1986). In Florida, blue tilapia (*Oreochromis aureus*) was accidentally released into public waters where it established itself successfully, resulting in a commercial fishery for this species (Hale *et al*. 1995).

*S. fontinalis* was successfully transplanted in four lakes in Ontario (Fraser, 1989) but it has not been translocated extensively in North America. Lake trout (*S. namaycush*) has been widely introduced also in response to declining populations due to the invasion of the sea lamprey. Evaluation of 183 introductions of this species in Ontario, showed that lake trout failed to establish in shallower lakes with large littoral zones and richer fish communities with potential predators (Evans and Olver 1995). Rainbow trout has been introduced into Appalachian streams where it dominates native brook trout (Clark and Rose, 1997).

Stocking of largemouth bass, its prey species, bluegill and other sport fishes is widely practised in the USA for recreational fisheries. Steelhead (*O. mykiss*) is extensively released to enhance recreational fisheries in British Columbia. Furthermore, grasscarp is stocked in the southern states to control aquatic weeds and various salmonid species are stocked in the Western States to restore and enhance river stocks. Important stocked species with high

reported hatchery production in North America are salmonids, pikeperch, striped bass, largemouth bass and bluegill.

### 3.4.8 Europe and the Former USSR

Relatively complete information is available about introductions in the Former USSR countries, the Scandinavia (Norway, Sweden and Finland), Germany, Italy and France. Introductions have been widespread in Europe. Important species are common carp, rainbow trout, pikeperch (*Stizostedion lucioperca*), *peled (Coregonus peled*), grass carp and lake trout (*Salvelinus namaycush*). European eel (*Anguilla anguilla*) is also widely released.

Chinese carps (grass, silver and bighead), bream (*Abramis brama*), common carp, pikeperch (*Stizostedion lucioperca*), wels catfish (*Silurus glanis*) and peled (*Coregonus peled*) have successfully adapted in Former USSR lakes and reservoirs (Berka, 1990). In Uzbekistan and Turkmenistan (Central Asia) a network of canals connecting a number of rivers and irrigation canals, has provided perfect migration pathways for redistribution of both the indigenous and introduced fish species. Interconnecting the rivers Amu-Darya, Syr-Darya and Zarafshan, their reservoirs, associated lakes, irrigation canals and new lakes formed in depressions from discharged drainage waters, has increased the number of fish species in most water bodies (Petr, 1995). The River Zarafshan in Uzbekistan, which had only 14 fish species before being connected to the Amu-Darya, now has 36 species (Urchinov, 1995). In Kazakhstan, The River Ili in Kazakhstan, the major tributary to Lake Balkhash, had 19 fish species prior to being dammed. By 1975, 24 fish species were recorded as a result of a number of introductions. In Lake Balkhash, the introduced common carp, pikeperch, bream, wels, asp and crucian carp represented 98% of the commercial catch in 1972, while the indigenous fish represented less than 2% (Petr and Mitrofanov, 1998).

Translocation of the sturgeon *Acipenser stellatus* from the Caspian Sea into the Azov Sea basin was ineffective as the introduced stock has an average body weight 13 percent less than the native Azov stocks (Tsvetnenko and Yu 1993). Pikeperch was successfully introduced into Lake Vozhe (Bolotova *et al* 1995) and rainbow trout has been introduced in Irkutsk Reservoir (Angara R.) in 1992 and has become widely distributed in the reservoir. There is however a concern for the ecological consequences of this invasion and the probable diffusion of this species in Lake Baikal, where it has been recorded already (Shirobokov 1993).

Vendace (*Coregonus albula*) was accidentally introduced to Lake Inari, a large oligotrophic lake in northern Finland in the 1950-1960's, and a significant fishery developed for this species (Mutenia and Salonen, 1992). In Norway, common carp has been widely introduced and is found to be established in 30 lakes and ponds in southern Norway (Kaalaas and Johansen, 1995). Pikeperch was introduced in Norwegian Lake Gjersjoeen and changed the fish community from one dominated by roach *(Rutilus rutilus*) to one dominated by pikeperch (Brabrand and Faafeng, 1993). North American crayfish (*Pacifastacus leniusculus)* invaded the fresh waters of Sweden and Finland and is considered responsible for the decline in native noble crayfish (*Astacus astacus*) through competition and disease transfer (Soederbaeck, 1995).

Information on introductions in Germany mainly relates to introduced crayfish, ruffe and grass carp for recreational fisheries. Seventeen species have established in open waters in Germany, among them rainbow trout, white fish (*Coregonid* spp.), *Lepomis* spp., *Salvelinus*

spp. and pikeperch. White fish species have also been introduced to Northern Italian lakes. Salmonids have been introduced to the high-elevation streams and lakes in the Pyrenees, France. Brown trout, rainbow trout, brook trout, lake trout and Arctic charr (*Salvelinus alpinus*) did acclimatise but only lake trout and Arctic charr reproduced in their new environment (Delacoste *et al*. 1997). These species contributed to the development of recreational fisheries in this region. Though Arctic charr is native to France, the introduced exotic species is more important, colonising 136 lakes (Machino, 1995).

## 3.4.9 Salient Points

- Global characterisation of fishery enhancements based on the information in ASFA abstracts is effective for classification of enhancement types, water body types and countries but less useful for enhancement purposes and measures of success-failure as these require more in depth analysis.
- Stocking and introductions are the most commonly used fishery enhancement techniques in inland water bodies
- Enhancement techniques to engineer the environment such as construction of fish attracting devices, establishment of fish sanctuaries and spawning habitats, fencing and restoration of floodplain-river connections and construction of appropriate fishways to fit the specific migration behaviour of the individual migratory species are used and often with considerable success, but evaluations and review of these techniques are scarce for inland water bodies on a global scale. Most information found about environmental engineering in the tropical regions relates to Asia.
- Information about fertilisation of inland water bodies as an enhancement technique is very scarce on global scale.
- Enhancement techniques among the continental Regions, are most diverse in Asia.
- Globally, introductions of Mozambique tilapia, common carp, rainbow trout, Nile tilapia an brook/sea trout have been important to enhance the production of fish as food and as income source.
- Introductions of tilapias have been relatively successful in large waterbodies due to the fact that this species establishes self-reproducing populations. Although regular stocking of this species is practised world-wide, probably because large numbers can easily be produced in hatcheries without sophisticated techniques, it is in many cases not clear if such stocking programmes significantly enhance fishery yields.
- Translocations and stocking of indigenous species have been an effective measure to enhance recreational fisheries in Australia.
- Common carp, rainbow trout, Atlantic salmon, Nile tilapia and brook/sea trout are the species that are most commonly produced in hatcheries for stocking of inland waters on a global scale.
- Stocking practises are least widespread in Africa, introductions are however relatively important in this continent.
- The number of references on stocking and introductions in North America and Europe and including the Former USSR, as derived from the ASFA literature, is significantly higher compared to the other continents.
- Introduction and stocking of grass carp has been generally successful in aquatic weed control.

- Introductions and stocking are most often carried out for production of food and generating income. Of second importance is enhancement for recreational fisheries.

## 3.5 Some Aspects of Rehabilitation and Mitigation for Inland Fisheries

### 3.5.1 Introduction

Almost all inland waters are heavily fished for food, recreation and for commercial gain. It has been recognised that inland waters throughout the world have long suffered degradation in the quality and quantity of water and of the aquatic and associated terrestrial environments. Construction of dams and weirs, water diversion for irrigation and other purposes, river channelisation, encroachment of agriculture, industries and housing estates into the margins of lakes, and some other human impacts have led to major modifications of inland water habitats with repercussions on fish stocks. Many inland water bodies have also been overfished. The combination of factors has usually led to a decline in fish, both in quantity and quality, with the lower valued fish surviving best in the stressed environments. Recognising the need for improvement, a number of countries, especially in northern America and in Europe, have initiated restoration programmes on water bodies and their catchments with the objective of bringing back the valuable fish species, and of restoring fish stocks in general to their previous composition and numbers, where possible, in order to improve biodiversity but also to support commercial and recreational fisheries.

### 3.5.2 Provisions for rehabilitation and mitigation

Institutions, whereby inland fisheries have been managed, have largely proved to be inadequate for the tasks of managing the fishery and protecting the interests of freshwater fish and fishers from impacts of other users of the water. This crisis is generating responses from the managers and users of the resources. Increasingly, traditional basic capture fisheries are being reinforced by a number of enhancement techniques (Section 3.4) aimed at improving the productivity of rivers, lakes and reservoirs. Some more effluent countries undertake a conscious effort to rehabilitate damaged ecosystems to re-create more favourable conditions for flora and fauna, including fish stocks.

Responding to the need for new approaches to fisheries management embracing conservation and environmental, as well as social and economic considerations, FAO has developed the concept of responsible fisheries and elaborated the Code of Conduct (FAO, 1995). Since then, appropriate technical guidelines in support of the implementation of the Code have been published (FAO Technical Guidelines). The recent Technical Guidelines No. 6 on Inland Fisheries (FAO Fisheries Department, 1997a) orient the interpretation of the various articles of the Code towards the specific needs of the inland fisheries sector. The special relevance of the Guidelines with regard to conservation and restoration of the aquatic environment is witnessed in several paragraphs where conservation and restoration are mentioned as two important management measures that can help to improve fisheries.

Furthermore, recommendations by various agencies and bodies, e.g. Council of Europe, HELCOM[7] and others, provide for the protection of fish species. The welfare of migrating species is of particular concern. The HELCOM recommendation 19/2 of March 1998 to the Governments of the Contracting Parties to the Helsinki Convention, *inter alia*, calls for undertaking all necessary measures feasible to improve the environmental conditions in present and potential salmon rivers to facilitate future natural reproduction of salmon. Such measures can be the improvement of water quality and quantity, restoration of rearing habitats, removal of man-made mechanical obstacles or by other measures facilitating salmon migration. It furthermore recommends not to build any new, permanent or temporary, mechanical obstacles that can prevent migration in salmon rivers.

Authorities should also take note that in many countries considerable attempts are now being made to try *to restore* what still is readily available in others, including the aquatic environment. Modern integrated management should, therefore, aim at decisions which do not put fisheries resources at unnecessary risk; prevention of loss of potential is much preferable to rehabilitation for obvious reasons including costs. Post-construction rehabilitation of valuable fish stocks is always costly and sometimes impossible. The construction of new dams and weirs can impair restoration attempts. In many cases it has been proven that a choice has had to be made between restoration of the fish populations and water regulation and storage for various purposes.

### 3.5.3 Need for action

The value of aquatic ecosystems lies in the sustained net benefits derived from the many goods and services they supply including various ecological functions, products for direct and indirect human consumption, energy, aesthetic and recreational benefits, and assimilative capacity of residues of human activities. Trade-offs between the net benefits of one use *vis-à-vis* those that can be derived from other uses are usually necessary. Ideally, the preferred combination of the various uses would result in the optimisation of sustained aggregate net benefits over time from the ecosystem. In practice, our understanding of complex ecosystems is insufficient to predict all present and future impacts of changes in the uses of different components of the ecosystems. As an essentially non-polluting and non-degrading activity, well-managed capture fisheries do not usually subtract from the benefits which other users can derive from inland aquatic ecosystems. Maintaining the integrity of these fisheries may place constraints on alternative uses of the aquatic ecosystem such as the generation of energy, sinks for pollutants, and abstractions for irrigation. Frequently, fisheries have been accorded lower priority because of the perception that alternative uses contribute more to society's welfare (FAO Fisheries Department, 1997a).

Conservation of inland aquatic resources should be viewed within the multipurpose use of river and lake basins. In most inland waters the principle constraints on the system and its living components come from human activities other than fishing. Governments, at all levels from central to local authorities, should set up mechanisms to conserve living aquatic resources compatible with the sustainable use of the basin, the aquatic ecosystem and the water for the whole range of economic and social purposes (FAO Fisheries Department, 1997a).

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[7] The Helsinki Commission: Baltic Marine Environment Protection Commission

As the major impacts arise from activities outside the fishery, the precautionary approach should be extended to all developments within the basin (FAO Fisheries Department, 1997a). This means that careful impact assessments of all non-fishery projects possibly affecting the fish and fishery should be made. Responsibility for the protection of aquatic ecosystems usually lies mostly outside the fishery. Authorities should, therefore, plan for the conservation of aquatic environments in the context of their multipurpose use. Activities such as dam construction for water supply and power, channelization for navigation and flood control, land drainage and wetland reclamation for agricultural and urban use, waste disposal from urban, mining, industrial and agricultural uses, abstractions for agricultural, industrial and urban supply all have a profound impact on the aquatic ecosystem. Many of these activities are considered fundamental to the functioning of modern society and are economically of such importance that their limitation in the interests of conservation become hypothetical. In many cases all that can be done is to keep the number of such interventions to a minimum and do a proper environmental impact assessment (EIA), thus limiting their impacts. If impacts are unavoidable, users of the aquatic system inflicting the damage should contribute to the mitigation of the effects of their activities. Where the environment has already been degraded rehabilitation and mitigation are amongst the tools of choice.

### 3.5.4 Definition

Rehabilitation is an attempt to restore a degraded aquatic environment and its aquatic living resources where the pressures producing the modification has eased or where new technologies can be introduced to reduce stresses (FAO, 1998c). The planning for rehabilitation needs careful delineation of the objectives to be achieved. However, the rehabilitated status is, by definition, not necessarily the same as the original before the environmental changes occurred.

Mitigation tries to improve ecological conditions where rehabilitation cannot be achieved due to irreversible changes to the environment or due to greater values attached to the alternative uses (FAO, 1998c). Wherever possible, however, rehabilitation should be opted for although in many cases conditions will only allow for mitigation.

### 3.5.5 Basic ecological features

Certain basic elements are required of an aquatic system so that it can retain its functionality. Wherever possible, maintenance of the ecologically valuable characteristics, which are needed to support a sustainable fish community, should be fought for, as later restoration, or even mitigation, has proven to be in most cases laborious, often impossible and not seldom, very costly.

Amongst the elements to maintain or restore is the longitudinal and lateral connectivity in rivers in the interests of conserving fish migration patterns. Through removal of transversal (weirs, dams) or lateral (levees) obstructions or the provision of fish pass mechanisms the migration routes can be improved. Main channel diversity in rivers, including e.g. meanders, point bars, bottom structure and vegetation etc., has to be restored or maintained.

The maintenance or restoration of floodplains and riverine wetlands cannot always be continuous along the river but provision should be made for reserves at the shortest possible intervals along the river where normal flood regimes are maintained.

Removal and control of all point-sources of pollution including industrial, urban and mining wastes must be opted for. Control of non-point source pollution, particularly of nutrients, into lakes, reservoirs and rivers is crucial.

All processes at basin level, but in particular deforestation, mining operations in rivers, extraction of sediments and changes in agricultural practice that can lead to massive siltation have to be controlled as they negatively affect the lives of lakes and reservoirs and destabilise river channels and floodplains.

### 3.5.6 Rehabilitation techniques and constraints

Appropriate technical solutions for rehabilitation and mitigation are available. Many of these techniques are compiled in the recent FAO/Fishing News Books publication “Rehabilitation of Rivers for Fish” (FAO, 1998c). In general, fisheries scientists and managers are now able to identify and prioritise problems impacting upon fisheries and aquatic communities as well as to identify and carry out appropriate technical solutions to these problems. However, the greatest challenges to development and maintenance of aquatic ecosystems for fisheries are the socio-economic aspects of restoration. In many cases, when potentially damaging schemes are being considered, or when alterations to existing schemes might allow rehabilitation work for fisheries, other stakeholders (e.g. planning or water resource management institutions) do not actively solicit the inputs of fisheries specialists at the early stages. It is, however, crucial that fisheries specialists be put in a position to interact with other disciplines at the earliest possible stage of projects. As most of the factors causing problems for fish communities are outside the immediate control of the fisheries sector, fisheries specialists need to broaden and strengthen their cause by interacting and making alliances with other interested parties, in seeking to limit damage to aquatic ecosystems, and to promote rehabilitation.

In parallel to conservation, mitigation or rehabilitation measures, strategies for long-term management, leading to an integrated management plan, have to be developed in order to assure sustainability.

### 3.5.7 FAO’s activities

FAO's Major Programme on Fisheries aims at promoting sustainable development of responsible fisheries and contributing to food security by advocating *inter alia* the restoration of the aquatic environment as a proper tool for management of inland waters for fisheries.

Through its Inland Water Resources and Aquaculture Service, the Fisheries Department of FAO is reviewing the inland water restoration activities on a world-wide scale to give advice to Member States through the appropriate instruments and bodies. The overall objective of the programme is to contribute, through improved management, to the sustainability of fisheries in inland waters for food as well as social and economic benefit in the member countries.

### 3.5.8 Review of river restoration

Considerable work on rehabilitation issues has been done, and is continuing to be done, under the auspices of EIFAC[8].

The FAO/Fishing News Books publication "Rehabilitation of Rivers for Fish" (FAO, 1998c) is based on the work done by the EIFAC Working Party on the Effects of Physical Modifications of the Aquatic Habitat on Fish Populations. These Guidelines have been compiled to provide technical advice on river restoration by elaborating on concepts and information requirements as well as on habitat modification and remedial measures. The Guidelines include chapters on habitat requirements of fish, river form and function, methods of habitat assessment, impact of man's activities on aquatic habitats, rehabilitation of channels and floodplains, protection and restoration of fish movements, management of aquatic vegetation and stock enhancement strategies.

The above mentioned Working Party took advantage of the recent International Symposium and Workshop on Management and Ecology of River Fisheries, which was organised by HIFI[9], in collaboration with EIFAC, and held in March 1998 in Hull, England, to discuss issues in relation to anthropogenic activities and fisheries as well as rehabilitation and mitigation activities. Effects of physical, chemical and biological factors which arise from shifts in land and aquatic resource use and which affect fisheries, were reviewed. The problems in terms of intensity of impact, spatial and temporal scale as well as the need for attention demand prioritisation for each river system separately. As a number of techniques for rehabilitation and mitigation are available, the new challenge is now the identification and solution of current socio-economic problems including financial limitations, socio-political demands and conflicts with other user groups. The Working Party also examined mechanisms for improving the success of rehabilitation schemes including improved post-project monitoring and evaluation, project planning and management, improved cost-benefit analysis as well as links to multiple resource management techniques.

A strategy for success would include evaluation and differentiation between "perceived" and "genuine" problems, and a definition of their relative magnitude. Means of funding need to be identified according to the scale of the problem. Realistic objectives for restoration have to be set in conjunction with allied groups, taking into account their political and economic motives. With regard to cost-benefit evaluation, an improved and standardised methodology is needed. More fisheries specialists should be trained in socio-economic assessment. This approach was anticipated as being more promising for and beneficial to fisheries than training socio-economists in fisheries matters. The post-restoration assessments of projects have to be improved or, where missing, incorporated, taking into account the relevant budget needs when planning. Furthermore, in seeking to promote the value of fish (or better, aquatic communities as a whole) the dialogue with politicians and the public has to be improved. The Working Party will continue addressing the issue along these lines.

[8] The European Inland Fisheries Advisory Commission
[9] Hull International Fisheries Institute, University of Hull, England

### 3.5.9 Review of lake and reservoir restoration

Until June 1998 a Sub-Group on "Methodologies for rehabilitation of lakes and reservoirs" existed under the umbrella of the EIFAC Working Party on Effects of Physical Modifications of the Aquatic Habitat on Fish Populations which had produced the above mentioned manual on "Rehabilitation of Rivers for Fish". In view of the importance of the topic and the fact that this sub-group would produce a concrete output, the 20th Session[10] of the European Inland Fisheries Advisory Commission, EIFAC, decided that it becomes an ad-hoc Working Party of its own (FAO, 1998d).

The task of this ad-hoc Working Party is to produce a companion manual to the "Rehabilitation of Rivers for Fish". The manual will touch upon typology of lakes and reservoirs, habitats and habitat requirements of fish, classification of lacustrine habitats, impact of man's activities on habitats, methods of rehabilitation, rehabilitation of regulated lakes, rehabilitation of eutrophicated lakes, rehabilitation of acidified lakes, management of spawning and nursery areas, management of aquatic vegetation, stock enhancement strategies and biomanipulation of reservoirs.

### 3.5.10 Review of consequences of lake, reservoir and catchment restoration for fish and fisheries world-wide

FAO is addressing the possibilities of lake, reservoir and catchment restoration for fish and fisheries in view of the potential preparation of guidelines to assist FAO member countries to first assess, then implement, activities to overcome their lake degradation problems.

The degradation of lake ecosystems in terms of, for example, water quality, change in water levels and loss of habitat has been aggravated over the past decades due to increasing direct and indirect human interventions in the catchments or pressures on the water bodies themselves. Some deteriorating effects on lake ecosystems, however, arose also from fisheries practices themselves, e.g. too heavy exploitation of stocks or introduction of exotic species.

According to Olem & Flock (1990), a lake problem can be defined as "*a limitation on the desired uses by a particular set of users*". That means, whenever the desired use is hampered, there will be a call for restoration by the particular user group affected. The objectives for lake restoration are thus potentially as manifold as the desired uses which can be affected. However, the greater the pressure by a certain user group, the more likely it is that the restoration will be undertaken. The most influential interests are those of direct vital importance to humans (e.g. drinking water supply) and high commercial interest in a broad sense. Thus, amongst the priority objectives, it is to overcome the limitations in drinking water supply, to improve aesthetics, to benefit tourism and recreation such as swimming, motorboating, sailing and canoeing. Only a few attempts seem to have been made where deleterious influences from sources external to fisheries have been managed or reduced with the direct objective to restore fish stocks in lakes.

In fact, a preliminary literature research on lake, reservoir and catchment restoration in relation to fish and fisheries did not bring to light many cases where restoration was carried out for benefiting lake or reservoir fishes or fisheries. Fish is mainly used as a tool for

[10] 20th Session of EIFAC took place from 29 June – 1 July 1998 in Praia do Carvoeiro, Portugal

achieving better water quality through biomanipulation. There can be benefits for fish and fisheries from restoration measures in the catchment, e.g. erosion control, sewage diversion and afforestation, but too seldom these measures are taken to primarily address the well-being of fish or fisheries. Benefits for fish and fisheries remain mainly a side-product.

FAO is carrying out an evaluation of the current state of the art of lake, reservoir and catchment restoration world-wide but with main emphasis on Europe and North America. It will specifically deal with the consequences of restoration for lake fish and fisheries. This concise review on which eventually the preparation of future manuals and guidelines could be based will address the problems which led to degradation of the ecosystem, the measures undertaken to overcome the problem or alleviate the situation (case studies) and the trends with regard to restoration techniques. However, the analysis should not only deal with the available technology, but treat in depth important issues like economic viability of the measures when applied, analysis of the difficulties for practical implementation, social implications, co-operation between various agencies involved and user groups concerned as well as provide a list of the worst affected water bodies.

Although mitigation and restoration of the environment are, and will presumably still remain for some time, initiatives of the more affluent countries, the outcome of the study is anticipated to be also beneficial for developing countries as lessons can be learnt from the attempts of restoration being made.

### 3.5.11 Technical Co-operation and promotion of the Code in the Baltic Countries for Restoration of Salmon: An Example

Many Estonian, Latvian and Lithuanian rivers have suffered the same fate as rivers in other countries bordering the Baltic Sea. Dams and weirs blocked the migratory path of salmonids and spawning and nursery areas have disappeared. Thus the issue of threatened migratory species, especially of salmon, and the restoration of some runs is of particular interest to all three Baltic countries. Not surprisingly, one of the major issues in salmon management is the conservation of wild Baltic salmon (McKinnell, 1997). Following recommendations by IBSFC[11] and HELCOM, Estonia, Latvia and Lithuania have prepared salmon river inventories for priority actions. In view of the plans to attain by 2010 for each salmon river a natural production of wild Baltic salmon of at least 50% of the best estimate potential, management measures, including restoration and mitigation, are being carefully considered. Opening of the former migration routes is one of the strategies considered.

In response to the request by the Government of the Republic of Lithuania, FAO, through a Technical Co-operation Project, is providing advice on the restoration of the migration routes for several migratory species. At one of the dams the existing fish lock will be improved for migration of various migrating species. At the second dam the Government is assisted in planning a new fish pass. In the framework of the project training, has been provided which touched not only upon matters strictly related to fish passes, e.g. the different types of devices, the importance of the selection criteria, the consideration costs involved and cost/benefit analyses but also upon the general ecological context. As a matter of fact, while restoring the ecosystem more natural solutions ought to be given preference compared to technical solutions. Well-designed monitoring programmes are crucial in view of sound fish

[11] IBFSC: International Baltic Sea Fishery Commission

stock management. Provision of information to, and education of, the public, e.g. through free access to visitor centres and, in the case of fish passes, observation chambers, are essential to increase the acceptance of restoration projects.

An Estonian Ministerial Delegation headed by the Minister of Environment, requested to be briefed on issues in relation to the Code of Conduct for Responsible Fisheries in FAO Headquarters in February 1998. As a follow-up to the visit, the promotion of the implementation of the Code was pursued in Estonia, as well as in Latvia, concentrating on management measures for responsible inland fisheries in relation to migratory fish species and river rehabilitation/conservation aspects (*viz*. Technical Guidelines for Responsible Fisheries, No. 6: Inland Fisheries). In this respect, reference is made to the FAO news and highlights article of 1997 entitled "Revival of northern Europe's rivers offers lessons for elsewhere" which can be found on the web (http://www.fao.org/news/1997/970403-e.htm).

**Activities by other organisations**

Some other organisations are active in the field of river and lake rehabilitation and mitigation. One of them is the EPA[12] Clean Lakes Program in the USA which has initiated in-lake restoration work as well as implementing management practices in the watershed. Their projects require the active participation of the local community. The mission of NALMS[13] is to forge partnerships among citizens, scientists, and professionals to foster the management and protection of lakes and reservoirs. Furthermore, the Everglades Restoration initiatives (Florida, USA) represent one of the largest ecosystem rehabilitation projects in the world.

In the Danube Delta, the establishment of the Danube Delta Biosphere Reserve under UNESCO's Man and the Biosphere Programme, made it possible to break dykes built in 1985 for rice production in the delta, and to allow the Danube to reflood the wetlands in 1994. This resulted in 18 species of fish recolonising this habitat, which was previously devoid of wild fish (Edwards, 1997).

Further upstream, some of the tributaries of the Danube are considered for, or already undergoing, restoration projects of certain river sections. On the initiative of the Ministry of Environment of the Czech Republic, some of the oxbows and tributaries on River Morava, cut off by channelisation, are being reconnected with the river. The rehabilitation of the river course is expected to lead to an increase in habitat diversity and to an increase the number of fish refugia (Penaz & Jurajda, 1993) thus leading to the re-establishment of fish communities formerly present in the unregulated river.

[12] EPA: United States Environmental Protection Agency
[13] NALMS: North American Lake Management Society

## 3.6 Importance of Recreational Fisheries

As has been noted (Box: Statistics), the use made of recreational fishery resources is under reported. Total recreational catch may be on the order of two million mt (Coates, 1995). Some recent examples indicate the importance of recreational fisheries:

- Amongst 22 European countries there are an estimated 21.3 million anglers (Hickley and Tompkins, 1998).
- In the USA 29.9 million anglers paid $US 447 million for fishing licenses in 1996, down from 30.3 million licenses in 1995 (Anon, 1997).
- In 1996, 18% of the population of the USA 16 years and older, 35 million persons, exerted 514 million angler-days in freshwaters expending $US 38.0 billion (U.S. Fish and Wildlife Service, 1997).
- Marine recreational catch from USA sounds, rivers and bays that was kept amounted to more than 30 000 mt in 1996 (Fisheries Statistics Division, 1997). About one half of the total marine recreational catch from all waters was released alive.
- In Canada 4.2 million anglers expended 55.5 million days and caught over 254 million fishes while expending C$7.4 billion of which C$4.9 billion was directly associated with the sport in 1995. Of the fishes caught some 113 million were kept[14] (Department of Fisheries and Oceans, Canada, 1998).

Despite the lack of data, it would be a mistake to assume that recreational fisheries are confined only to developed countries and that the only output is enjoyment. In fact, promotion of recreational fishing as national and international income-generating activities is being contemplated or practised in many developing countries, among them Brazil, Malaysia and Zimbabwe. In another light, fishing for subsistence often has a high recreational value.

[14] http://www.dfompo.gc.ca/communic/statistics/recfsh95/content2.htm

# 4. CONCLUSIONS

- Based on total inland capture for the period 1984-1997 it is clear that increasing use is being made of inland fishery resources. The average annual increase has been about 138 000 t (about 2%).

- Asia, the most important continent, is where the largest increases in inland fishery resource use have been occurring with an annual average rate of increase of 4% since 1984 and 7% since 1992. Widespread use of inland fishery enhancements along with human-induced eutrophication are responsible for the relatively high outputs achieved in comparison with the land and water resources that are available there. In Africa, the second most important region, the 14-year trend is for an average annual increase of about 2%. In contrast, inland capture is on a trend for decrease in the former USSR (-7%) and in North America (-4%). The 14-year trend for Europe is for a slight decrease (-1%) while South America is increasing slightly (1%). Oceania has been stable over the long term.

- The nominal inland capture amounted to about 7.7 million t in 1997. Actual inland capture is considerably greater than the amounts reported to FAO. The factor is at least two overall, but may be as high as three in some instances.

- There is an urgent need for better data on inland fisheries that can be interpreted in both economic and ecological terms. For the latter, reporting should be by individual water bodies, or by clusters of small water bodies, with the priority on those that are largest and those shared among countries. Capture from all water bodies should be reported according to river and lake basin frameworks. Reporting at species level, or at least by species groups, needs to be fully implemented. The cost of improving inland fishery data collection is high, but failure to do so also is costly in terms of lessened or lost opportunities to increase food security and other economic and social benefits from inland fishery resources.

- Despite the increases in inland fish capture being achieved by many countries and in several continental regions, degradation of the environment and loss of fishery habitat are the pre-eminent concerns for the sustainability of inland fisheries. In many areas the environment will continue to be degraded and more fish habitat will be lost. This situation must be reversed. The need for significant effort to prevent and reduce environmental degradation—as well as protecting inland fishery resources—offers may opportunities for co-operation between stakeholders concerned with, for example, fisheries, agriculture, forestry, water use and environmental protection. Restoration and rehabilitation are practised where public concern is manifest and finances are available.

- Introductions and stocking are the most widely practised enhancements in inland waters. The future of many inland fisheries will include the expanded use of fishery enhancements. In some continental areas there is very good unrealised potential for enhancement practices. However, implementation of enhancements has to be considered in economic and social terms and enhancements are not without environmental risks. Unsuccessful attempts to enhance along with environmental problems will be a drag on significant increases in inland capture.

- The relative importance of stocking as an inland fishery enhancement underlines the essential role of fish culture in sustaining many inland fisheries and for the expansion of culture-based fisheries. Successful stocking programmes will require, first of all, well-thought out strategies, then, efficient seed production and broodstock management, management of genetic resources and maintenance of well-functioning aquatic ecosystems.

- Recreational fisheries provide not only sport, but also generate enormous economic activity. A challenge is to accommodate both recreation and food fisheries where the latter are important for the economic and nutritional well-being of the populace.

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# 6. ANNEX I

# INLAND CAPTURE STATISTICAL DATA

## Table A1. Africa

**Africa North of the Sahara**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Egypt | 114 129 | 136 255 | 144 536 | 128 051 | 167 781 | 153 729 | 175 669 | 155 953 | 180 400 | 186 700 | 199 300 | 229 000 | 230 710 | 246 100 | 0.11 |
| Morocco | 1 310 | 1 320 | 1 310 | 1 305 | 1 243 | 1 837 | 1 404 | 1 294 | 1 794 | 1 617 | 1 750 | 1 500 | 1 500 | 2 100 | 0.06 |
| Tunisia | - | - | - | - | - | - | - | - | - | 400 | 243 | 440 | 706 | 1 010 | 0.68 |
| Algeria | 15 | 65 | 128 | 102 | 88 | 46 | 104 | 20 | 20 | 20 | 20 | 15 | 13 | 10 | (0.27) |

**Trans-Saharan Africa**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mali | 54 708 | 54 178 | 61 002 | 55 701 | 55 858 | 71 825 | 70 535 | 68 749 | 68 467 | 64 300 | 62 850 | 132 900 | 111 910 | 99 550 | 0.13 |
| Chad | 50 000 | 55 000 | 60 000 | 70 000 | 58 000 | 64 400 | 70 000 | 60 000 | 80 000 | 87 300 | 80 000 | 90 000 | 100 000 | 85 000 | 0.10 |
| Sudan | 28 452 | 25 881 | 22 752 | 26 000 | 28 000 | 29 000 | 30 000 | 31 600 | 33 000 | 37 500 | 40 000 | 40 000 | 40 500 | 42 000 | 0.10 |
| Niger | 2 991 | 1 993 | 2 337 | 2 269 | 2 479 | 4 722 | 3 318 | 3 124 | 2 041 | 2 156 | 2 491 | 3 541 | 4 135 | 6 328 | 0.11 |
| Mauritania | 6 000 | 6 000 | 6 000 | 6 000 | 6 000 | 6 000 | 6 000 | 6 000 | 5 000 | 5 000 | 5 000 | 5 500 | 6 000 | 6 000 | (0.02) |
| Somalia | 300 | 300 | 400 | 450 | 500 | 500 | 400 | 300 | 300 | 250 | 300 | 300 | 250 | 300 | (0.06) |

**East Africa South of the Sahara**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tanzania, United Rep. of | 237 303 | 257 883 | 265 738 | 303 398 | 343 722 | 327 157 | 356 956 | 271 970 | 275 150 | 294 582 | 247 614 | 317 029 | 308 431 | 306 750 | 0.02 |
| Uganda | 212 300 | 160 800 | 197 600 | 200 000 | 214 291 | 212 205 | 245 223 | 214 570 | 264 900 | 219 814 | 213 129 | 208 789 | 195 088 | 218 026 | 0.02 |
| Congo, Dem. Rep. of the | 146 319 | 146 220 | 153 811 | 159 277 | 159 241 | 163 240 | 159 300 | 162 050 | 184 040 | 192 589 | 152 117 | 154 751 | 159 037 | 158 367 | 0.01 |
| Kenya | 84 798 | 99 647 | 113 465 | 124 180 | 129 819 | 137 989 | 190 993 | 190 305 | 155 644 | 176 435 | 198 805 | 187 241 | 174 181 | 154 939 | 0.10 |
| Zambia | 64 281 | 67 368 | 67 504 | 62 474 | 59 437 | 65 638 | 63 311 | 62 883 | 63 649 | 60 652 | 65 526 | 66 465 | 61 562 | 65 902 | - |
| Malawi | 64 945 | 61 892 | 72 670 | 88 393 | 78 602 | 70 554 | 73 903 | 63 506 | 69 261 | 67 951 | 58 579 | 53 664 | 63 569 | 56 340 | (0.04) |
| Madagascar | 32 310 | 33 836 | 39 819 | 39 806 | 39 771 | 29 985 | 29 960 | 27 500 | 27 500 | 30 000 | 30 000 | 30 000 | 30 000 | 30 000 | (0.04) |
| Burundi | 11 361 | 11 369 | 11 840 | 12 009 | 11 677 | 10 762 | 17 395 | 20 994 | 23 033 | 22 000 | 20 650 | 21 101 | 3 041 | 20 296 | 0.08 |
| Zimbabwe | 16 277 | 17 260 | 18 802 | 19 028 | 22 057 | 23 895 | 25 607 | 22 025 | 21 601 | 21 230 | 20 188 | 16 405 | 16 311 | 18 056 | - |
| Mozambique | 3 500 | 3 500 | 3 767 | 3 267 | 3 248 | 3 500 | 3 500 | 3 800 | 3 800 | 4 689 | 4 925 | 5 093 | 7 510 | 11 505 | 0.18 |
| Ethiopia | 3 700 | 3 500 | 3 500 | 3 500 | 3 343 | 2 679 | 3 773 | 4 109 | 4 485 | 4 175 | 5 285 | 6 325 | 8 770 | 10 370 | 0.19 |
| Rwanda | 786 | 906 | 1 485 | 1 630 | 1 290 | 1 472 | 2 350 | 3 503 | 3 644 | 3 500 | 3 400 | 3 300 | 3 000 | 3 100 | 0.20 |

**West Africa South of the Sahara**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nigeria | 104 190 | 80 141 | 101 892 | 97 858 | 100 272 | 89 590 | 91 617 | 77 919 | 93 281 | 95 627 | 103 800 | 117 903 | 89 521 | 110 510 | 0.02 |
| Senegal | 15 000 | 15 000 | 15 000 | 15 000 | 17 000 | 17 000 | 17 000 | 17 550 | 24 750 | 27 650 | 28 000 | 35 000 | 47 500 | 80 600 | 0.28 |
| Ghana | 41 000 | 43 000 | 53 000 | 55 000 | 57 630 | 57 660 | 58 000 | 57 000 | 56 000 | 52 000 | 54 700 | 60 000 | 73 580 | 70 000 | 0.06 |
| Benin | 31 385 | 29 989 | 29 985 | 31 973 | 28 541 | 32 898 | 30 326 | 27 715 | 26 566 | 32 805 | 32 716 | 37 449 | 34 193 | 32 871 | 0.02 |
| Cameroon | 20 000 | 20 000 | 20 000 | 20 000 | 20 000 | 21 000 | 22 000 | 22 000 | 22 000 | 23 000 | 23 000 | 21 000 | 23 000 | 25 000 | 0.03 |
| Congo, Republic of | 13 518 | 13 561 | 14 009 | 15 269 | 19 423 | 23 890 | 26 017 | 26 964 | 21 049 | 27 850 | 24 752 | 26 811 | 25 872 | 18 987 | 0.09 |
| Sierra Leone | 16 500 | 16 500 | 16 000 | 16 000 | 16 000 | 16 000 | 15 000 | 13 000 | 14 000 | 14 000 | 15 000 | 15 000 | 14 500 | 14 500 | (0.03) |
| Central African Republic | 13 000 | 13 000 | 13 000 | 13 000 | 13 000 | 13 000 | 13 000 | 13 500 | 13 000 | 13 150 | 12 650 | 12 900 | 12 650 | 12 500 | - |
| Côte d'Ivoire | 22 410 | 26 400 | 28 000 | 27 200 | 28 400 | 30 500 | 27 500 | 23 401 | 17 404 | 14 477 | 15 604 | 11 335 | 12 000 | 12 032 | (0.14) |
| Gabon | 1 800 | 1 800 | 1 979 | 1 900 | 1 900 | 1 900 | 2 000 | 2 000 | 2 000 | 3 500 | 4 500 | 7 648 | 9 433 | 9 441 | 0.34 |
| Burkina Faso | 7 300 | 7 410 | 7 610 | 7 810 | 7 909 | 8 009 | 7 009 | 7 007 | 7 503 | 7 000 | 8 000 | 8 000 | 8 000 | 8 000 | 0.01 |
| Angola | 7 500 | 7 500 | 8 000 | 8 000 | 8 000 | 8 000 | 8 000 | 7 000 | 7 000 | 7 000 | 7 000 | 6 000 | 6 000 | 6 000 | (0.05) |
| Togo | 3 500 | 3 500 | 3 505 | 3 505 | 3 509 | 4 509 | 4 908 | 4 908 | 5 500 | 6 000 | 5 000 | 4 998 | 5 000 | 5 000 | 0.08 |
| Liberia | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | 4 000 | - |
| Guinea | 1 800 | 2 000 | 2 500 | 3 000 | 3 000 | 3 000 | 3 000 | 3 500 | 4 000 | 4 600 | 3 800 | 3 100 | 2 780 | 3 600 | 0.08 |
| Gambia | 2 700 | 2 700 | 2 700 | 2 700 | 2 700 | 2 700 | 2 700 | 2 500 | 2 500 | 2 400 | 2 400 | 2 500 | 2 500 | 2 500 | (0.02) |
| Botswana | 1 500 | 1 500 | 1 700 | 1 900 | 1 900 | 1 900 | 1 900 | 1 900 | 1 900 | 2 000 | 2 000 | 2 000 | 2 100 | 2 000 | 0.04 |
| Namibia | 400 | 700 | 923 | 951 | 979 | 1 009 | 1 039 | 1 070 | 1 102 | 1 196 | 996 | 1 195 | 1 195 | 1 495 | 0.11 |
| Equatorial Guinea | 400 | 400 | 450 | 400 | 400 | 400 | 400 | 350 | 370 | 600 | 700 | 450 | 900 | 850 | 0.13 |
| South Africa | 800 | 800 | 800 | 800 | 815 | 821 | 823 | 825 | 832 | 832 | 800 | 800 | 850 | 850 | 0.01 |
| Guinea- Bissau | 50 | 80 | 80 | 100 | 150 | 200 | 200 | 200 | 200 | 250 | 250 | 250 | 250 | 250 | 0.20 |
| Swaziland | 82 | 78 | 82 | 81 | 90 | 70 | 65 | 60 | 60 | 68 | 65 | 60 | 60 | 65 | (0.06) |
| Lesotho | - | - | - | - | - | 5 | 10 | 10 | 16 | 22 | 22 | 26 | 28 | 30 | 0.48 |

## Table A2. Asia

**Western Asia**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pakistan | 62 106 | 66 588 | 75 493 | 83 131 | 89 748 | 95 299 | 103 158 | 103 153 | 109 087 | 109 185 | 118 703 | 121 405 | 142 092 | 153 000 | 0.13 |
| Turkey | 44 270 | 42 769 | 40 229 | 41 759 | 48 499 | 42 833 | 37 204 | 39 368 | 40 495 | 44 801 | 45 067 | 47 976 | 49 600 | 50 460 | 0.02 |
| Syrian Arab Republic | 2 081 | 1 835 | 1 809 | 1 880 | 1 242 | 886 | 1 455 | 3 143 | 2 584 | 2 535 | 3 570 | 3 832 | 3 103 | 3 535 | 0.15 |
| Israel | 1 667 | 1 482 | 1 625 | 1 821 | 1 367 | 1 930 | 2 113 | 2 221 | 2 214 | 1 813 | 1 478 | 1 214 | 1 845 | 2 445 | 0.03 |
| Jordan | 100 | 150 | 200 | 250 | 300 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 0.12 |
| Cyprus | - | - | - | - | 1 | 2 | - | 3 | - | - | 5 | 65 | 64 | 70 | 0.71 |
| Lebanon | - | - | - | - | - | - | - | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 0.47 |

**Southeast Asia**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Indonesia | 277 415 | 272 426 | 273 016 | 276 319 | 297 015 | 315 192 | 293 537 | 294 477 | 300 941 | 308 649 | 336 141 | 329 700 | 335 707 | 339 310 | 0.04 |
| Thailand | 109 036 | 86 253 | 97 108 | 88 718 | 95 299 | 119 322 | 135 457 | 138 121 | 135 239 | 175 140 | 193 918 | 186 665 | 211 298 | 228 898 | 0.16 |
| Philippines | 299 232 | 260 247 | 265 086 | 244 631 | 231 829 | 222 277 | 236 826 | 233 241 | 229 673 | 210 775 | 204 323 | 186 006 | 177 355 | 159 114 | -0.08 |
| Myanmar | 144 010 | 146 800 | 145 560 | 139 498 | 139 147 | 136 287 | 137 500 | 149 117 | 130 525 | 146 552 | 150 720 | 151 748 | 169 300 | 157 415 | 0.02 |
| Cambodia | 55 093 | 56 400 | 64 204 | 62 157 | 61 200 | 50 500 | 65 100 | 74 700 | 68 900 | 67 900 | 65 000 | 72 499 | 63 510 | 73 000 | 0.04 |
| Viet Nam | 123 279 | 121 150 | 132 666 | 136 000 | 135 000 | 131 000 | 111 000 | 101 000 | 90 500 | 80 500 | 70 500 | 71 000 | 66 000 | 66 000 | -0.13 |
| Lao, People's Dem. Rep. | 23 500 | 22 000 | 21 000 | 22 000 | 21 000 | 20 000 | 18 000 | 17 000 | 18 000 | 18 500 | 22 200 | 25 850 | 25 850 | 26 000 | 0.02 |
| Malaysia | 2 819 | 3 986 | 4 181 | 737 | 996 | 1 079 | 1 276 | 1 458 | 1 773 | 1 971 | 2 064 | 3 939 | 4 000 | 3 949 | 0.06 |
| Brunei Darussalam | 84 | 95 | 161 | 118 | 106 | 128 | 104 | 105 | 25 | 25 | 4 | 7 | 15 | 17 | -0.31 |

**South Asia**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| India | 585 136 | 471 900 | 534 266 | 454 836 | 445 995 | 405 065 | 592 378 | 471 566 | 373 287 | 575 905 | 567 874 | 623 378 | 648 425 | 728 887 | 0.05 |
| Bangladesh | 468 289 | 454 612 | 441 000 | 406 327 | 409 815 | 404 876 | 400 099 | 430 843 | 429 205 | 452 109 | 517 746 | 527 739 | 535 617 | 536 055 | 0.04 |
| Sri Lanka | 27 575 | 29 243 | 31 390 | 31 965 | 33 012 | 34 720 | 26 765 | 19 832 | 17 500 | 15 000 | 9 500 | 12 000 | 15 750 | 25 250 | -0.13 |

**East Asia and China**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| China | 472 315 | 513 415 | 593 772 | 647 307 | 721 102 | 829 491 | 864 144 | 998 961 | 998 028 | 1 182 390 | 1 327 785 | 1 607 385 | 1 762 860 | 1 886 967 | 0.23 |
| Japan | 106 507 | 110 127 | 106 244 | 130 419 | 100 333 | 103 243 | 112 070 | 107 366 | 97 043 | 91 152 | 92 506 | 91 756 | 93 757 | 84 281 | -0.04 |
| Korea, Dem. People's Rep | 84 000 | 80 000 | 75 000 | 70 000 | 65 000 | 65 000 | 45 000 | 40 000 | 35 000 | 35 000 | 20 000 | 20 000 | 20 000 | 20 000 | -0.26 |
| Korea, Republic of | 48 283 | 49 072 | 51 934 | 47 807 | 29 396 | 23 797 | 27 080 | 22 609 | 25 487 | 12 263 | 10 492 | 9 651 | 8 088 | 6 935 | -0.31 |
| Taiwan Province of China | 2 269 | 2 028 | 1 835 | 2 039 | 2 853 | 8 321 | 3 142 | 2 191 | 1 566 | 1 216 | 1 059 | 695 | 407 | 403 | -0.2 |

**Central Asia**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Iran (Islamic Rep. of) | 4 238 | 4 401 | 8 994 | 16 471 | 20 090 | 24 007 | 42 939 | 60 497 | 60 016 | 75 021 | 89 157 | 88 800 | 109 286 | 111 445 | 0.39 |
| Iraq | 11 524 | 11 500 | 11 000 | 11 000 | 16 461 | 17 938 | 18 875 | 13 360 | 17 530 | 17 808 | 20 926 | 22 955 | 19 049 | 20 519 | 0.11 |
| Nepal | 2 863 | 5 811 | 5 281 | 5 281 | 6 975 | 5 686 | 5 288 | 5 281 | 5 895 | 7 418 | 7 340 | 11 230 | 11 230 | 11 230 | 0.16 |
| Afghanistan | 800 | 800 | 800 | 1 000 | 1 000 | 1 000 | 1 100 | 1 100 | 1 200 | 1 200 | 1 300 | 1 300 | 1 300 | 1 250 | 0.09 |
| Bhutan | 250 | 280 | 280 | 300 | 300 | 300 | 300 | 295 | 315 | 320 | 310 | 310 | 300 | 300 | 0.02 |
| Mongolia | 370 | 374 | 412 | 383 | 281 | 254 | 124 | 100 | 120 | 165 | 184 | 158 | 231 | 181 | -0.17 |
| Others | 426 | 270 | 218 | 214 | 130 | 82 | 60 | 32 | 24 | 25 | 23 | - | - | - | -0.49 |

## Table A3. Europe

**Eastern Europe**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Poland | 14 540 | 8 801 | 10 752 | 10 241 | 8 209 | 8 209 | 18 600 | 18 500 | 20 950 | 31 391 | 27 500 | 24 889 | 22 037 | 22 077 | 0.17 |
| Hungary | 22 704 | 18 612 | 19 065 | 18 811 | 20 324 | 14 969 | 16 288 | 14 944 | 15 206 | 13 912 | 14 058 | 13 506 | 13 044 | 12 582 | (0.09) |
| Yugoslavia SFR | 15 098 | 15 684 | 16 073 | 15 174 | 16 449 | 15 129 | 12 404 | 6 000 | | | | | | | (0.45) |
| Yugoslavia, Fed. Rep. of | | | | | | | | | 6 060 | 4 769 | 4 992 | 4 766 | 4 943 | 5 186 | (0.02) |
| Bosnia and Herzegovina | | | | | | | | | 3 000 | 2 500 | 2 400 | 2 500 | 2 600 | 2 550 | (0.02) |
| Slovenia | | | | | | | | | 293 | 297 | 317 | 292 | 265 | 280 | (0.02) |
| Croatia | | | | | | | | | 198 | 284 | 340 | 364 | 434 | 408 | 0.11 |
| Romania | 10 919 | 16 017 | 18 206 | 26 679 | 26 584 | 19 582 | 13 236 | 10 988 | 9 890 | 8 562 | 10 598 | 9 048 | 6 145 | 4 282 | (0.18) |
| Czech Republic | | | | | | | | | | 3 185 | 3 955 | 3 929 | 3 524 | 3 321 | - |
| Czechoslovakia | 3 700 | 4 000 | 4 300 | 4 517 | 4 390 | 3 966 | 4 304 | 4 300 | 4 350 | | | | | | (0.32) |
| Slovakia | | | | | | | | | | 1 184 | 1 627 | 1 948 | 1 412 | 1 386 | 0.01 |
| Bulgaria | 1 093 | 1 410 | 2 376 | 1 322 | 1 089 | 1 473 | 1 627 | 1 456 | 1 611 | 1 675 | 995 | 752 | 1 123 | 1 881 | (0.02) |

**Northern Europe**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Finland | 66 056 | 66 031 | 55 221 | 54 389 | 49 300 | 48 973 | 49 310 | 49 108 | 51 407 | 51 522 | 47 895 | 48 436 | 47 618 | 47 618 | (0.05) |
| Sweden | 2 412 | 2 108 | 2 237 | 2 010 | 2 184 | 2 162 | 2 068 | 2 135 | 2 308 | 2 273 | 2 254 | 1 934 | 1 810 | 2 011 | (0.02) |
| Norway | 356 | 388 | 370 | 432 | 280 | 476 | 483 | 541 | 580 | 435 | 432 | 413 | 338 | 966 | 0.09 |
| Iceland | 410 | 467 | 546 | 500 | 643 | 527 | 676 | 756 | 886 | 907 | 698 | 739 | 608 | 404 | 0.05 |

**Southern Europe**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Greece | 7 755 | 6 516 | 8 302 | 8 070 | 7 353 | 7 350 | 8 167 | 7 836 | 9 007 | 10 776 | 13 293 | 17 585 | 16 483 | 16 000 | 0.17 |
| Italy | 20 553 | 15 419 | 17 737 | 12 703 | 19 393 | 19 909 | 13 050 | 9 523 | 9 075 | 9 515 | 9 921 | 10 035 | 8 976 | 10 393 | (0.14) |
| Spain | 10 238 | 10 200 | 10 700 | 8 595 | 9 386 | 10 005 | 8 620 | 8 937 | 8 950 | 9 150 | 9 100 | 9 489 | 9 490 | 10 000 | (0.01) |
| Albania | 2 432 | 2 772 | 2 784 | 2 034 | 2 436 | 2 309 | 1 696 | 802 | 916 | 888 | 736 | 219 | 317 | 180 | (0.33) |
| Macedonia, Fmr Yug Rp of | | | | | | | | | 195 | 164 | 196 | 208 | 78 | 128 | (0.09) |

**Western Europe**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Germany | 6 757 | 7 774 | 8 351 | 7 844 | 9 238 | 7 982 | 10 731 | 9 041 | 8 770 | 10 837 | 10 908 | 22 987 | 22 987 | 22 916 | 0.22 |
| France | 2 000 | 3 050 | 3 533 | 2 772 | 3 695 | 3 020 | 3 500 | 4 000 | 4 350 | 4 400 | 4 450 | 4 500 | 4 540 | 4 540 | 0.10 |
| Ireland | 88 | 87 | 87 | 221 | 3 103 | 6 404 | 2 936 | 2 938 | 2 991 | 2 929 | 3 604 | 3 761 | 3 806 | 3 804 | 0.24 |
| Netherlands | 3 856 | 3 814 | 4 170 | 4 979 | 5 151 | 3 646 | 2 587 | 3 509 | 2 318 | 1 636 | 2 446 | 4 107 | 2 157 | 2 293 | (0.11) |
| Switzerland | 3 841 | 4 294 | 4 386 | 4 271 | 3 973 | 3 303 | 3 158 | 3 599 | 2 715 | 1 822 | 1 481 | 1 588 | 1 841 | 1 859 | (0.17) |
| United Kingdom | 1 431 | 1 790 | 2 097 | 1 808 | 1 201 | 2 833 | 2 666 | 2 057 | 2 035 | 1 909 | 2 191 | 2 146 | 1 930 | 1 481 | 0.01 |
| Belgium | | 494 | 498 | 458 | 474 | 514 | 511 | 511 | 511 | 511 | 511 | 511 | 511 | 511 | 0.08 |
| Austria | 700 | 700 | 640 | 600 | 600 | 550 | 533 | 500 | 479 | 420 | 388 | 404 | 450 | 465 | (0.09) |
| Denmark | 464 | 362 | 433 | 403 | 389 | 436 | 392 | 389 | 659 | 337 | 262 | 264 | 196 | 232 | (0.09) |

## Table A4. Former USSR

**Western Area and Russian Federation**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Russian Federation | | | | | 436 986 | 428 176 | 355 953 | 289 188 | 275 028 | 216 647 | 217 858 | 212 874 | 233 272 | 227 091 | (0.13) |
| Un. Sov. Soc. Rep. | 620 766 | 629 398 | 617 669 | 654 605 | | | | | | | | | | | (0.66) |
| Ukraine | | | | | 50 840 | 46 447 | 35 493 | 31 252 | 24 801 | 13 189 | 14 786 | 6 847 | 9 468 | 6 215 | (0.33) |
| Estonia | | | | | 4 838 | 5 935 | 4 552 | 1 870 | 3 509 | 2 411 | 1 909 | 2 366 | 2 361 | 2 439 | (0.17) |
| Lithuania | | | | | 2 555 | 3 600 | 5 970 | 2 450 | 1 522 | 1 130 | 1 187 | 1 260 | 1 295 | 1 712 | (0.21) |
| Georgia | | | | | 628 | 219 | 115 | 211 | 209 | 211 | 200 | 219 | 595 | 734 | 0.11 |
| Latvia | | | | | 1 554 | 249 | 129 | 525 | 551 | 553 | 495 | 514 | 536 | 544 | (0.08) |
| Belarus | | | | | 2 848 | 3 640 | 2 988 | 793 | 503 | 508 | 384 | 256 | 251 | 300 | (0.45) |
| Moldova, Republic of | | | | | 1 460 | 1 865 | 2 331 | 47 | 60 | 90 | 20 | 30 | 40 | 50 | (0.56) |

**Southern Area**

| | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kazakhstan | 77 972 | 80 458 | 77 528 | 69 308 | 65 124 | 56 700 | 46 433 | 48 402 | 44 273 | 40 323 | (0.12) |
| Turkmenistan | 44 445 | 50 513 | 42 485 | 40 792 | 31 591 | 15 650 | 15 184 | 9 490 | 9 012 | 8 486 | (0.30) |
| Azerbaijan | 55 340 | 52 785 | 40 449 | 37 487 | 29 510 | 20 999 | 18 162 | 9 271 | 8 512 | 8 000 | (0.31) |
| Uzbekistan | 5 750 | 4 525 | 4 801 | 3 123 | 9 346 | 4 358 | 3 095 | 3 611 | 1 494 | 3 075 | (0.12) |
| Armenia | 2 419 | 956 | 714 | 343 | 601 | 570 | 560 | 520 | 440 | 400 | (0.27) |
| Tajikistan | 309 | 280 | 284 | 256 | 255 | 242 | 248 | 260 | 240 | 200 | (0.05) |
| Kyrgyzstan | 212 | 312 | 327 | 225 | 201 | 127 | 131 | 185 | 169 | 150 | (0.12) |

## Table A5. Latin America

**Caribbean Rim and Island States**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | 102 808 | 88 526 | 103 950 | 153 696 | 150 795 | 150 780 | 119 260 | 115 608 | 111 882 | 114 613 | 111 125 | 122 020 | 122 501 | 113 552 | - |
| Venezuela | 21 073 | 16 170 | 19 886 | 27 441 | 30 710 | 22 756 | 18 627 | 21 095 | 20 114 | 28 251 | 37 638 | 59 744 | 55 050 | 57 387 | 0.20 |
| Colombia | 53 354 | 47 708 | 55 066 | 61 069 | 48 685 | 36 113 | 33 940 | 19 431 | 33 759 | 30 538 | 34 983 | 23 524 | 23 061 | 20 609 | (0.16) |
| Guatemala | 54 | 47 | 120 | 523 | 473 | 534 | 2 599 | 2 779 | 3 702 | 4 228 | 3 776 | 4 025 | 4 000 | 5 121 | 0.41 |
| Costa Rica | 213 | 300 | 300 | 300 | 300 | 300 | 300 | 526 | 406 | 865 | 1 027 | 1 087 | 2 128 | 3 500 | 0.45 |
| El Salvador | 1 695 | 2 791 | 1 862 | 1 680 | 703 | 4 027 | 3 641 | 4 353 | 5 136 | 4 461 | 3 818 | 4 325 | 2 742 | 2 821 | 0.11 |
| Cuba | 1 817 | 1 660 | 2 157 | 841 | 340 | 286 | 213 | 161 | 276 | 933 | 424 | 694 | 872 | 1 172 | (0.17) |
| Dominican Republic | 1 769 | 2 521 | 843 | 1 850 | 1 200 | 1 884 | 1 620 | 662 | 1 024 | 2 255 | 3 820 | 2 160 | 1 205 | 1 068 | 0.01 |
| Nicaragua | 118 | 84 | 55 | 170 | 114 | 114 | 150 | 256 | 348 | 547 | 824 | 538 | 1 137 | 1 000 | 0.43 |
| Guyana | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 800 | 700 | 800 | 625 | (0.02) |
| Jamaica | 122 | - | - | 625 | 332 | 787 | 900 | 700 | 700 | 650 | 700 | 700 | 700 | 600 | 0.10 |
| Haiti | 300 | 300 | 300 | 300 | 300 | 300 | 350 | 400 | 500 | 600 | 500 | 500 | 500 | 500 | 0.12 |
| Suriname | 145 | 228 | 109 | 107 | 126 | 350 | 350 | 360 | 561 | 187 | 138 | 139 | 150 | 150 | 0.01 |
| Honduras | 84 | 32 | 77 | 8 | 50 | 36 | 45 | 41 | 85 | 86 | 92 | 127 | 98 | 100 | 0.16 |
| Panama | 50 | 50 | 202 | 248 | 37 | - | 15 | 50 | 80 | 28 | 285 | 130 | 80 | 91 | 0.03 |

**South America**

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brazil | 201 102 | 200 678 | 213 163 | 219 669 | 190 566 | 193 290 | 191 115 | 193 240 | 182 540 | 186 990 | 191 485 | 193 042 | 210 277 | 210 000 | - |
| Peru | 29 732 | 27 791 | 32 548 | 36 378 | 39 427 | 33 799 | 28 321 | 43 063 | 32 734 | 38 290 | 48 837 | 50 789 | 28 890 | 32 221 | 0.04 |
| Paraguay | 5 000 | 7 500 | 13 000 | 10 000 | 10 000 | 11 000 | 12 490 | 12 990 | 17 985 | 15 985 | 16 900 | 17 810 | 21 650 | 27 650 | 0.20 |
| Argentina | 9 536 | 9 715 | 8 825 | 7 935 | 10 595 | 10 801 | 10 331 | 10 281 | 11 227 | 11 546 | 12 121 | 11 863 | 11 862 | 12 000 | 0.05 |
| Bolivia | 4 105 | 4 170 | 3 871 | 4 226 | 4 332 | 5 676 | 6 909 | 5 167 | 4 905 | 5 518 | 5 353 | 5 692 | 5 988 | 6 038 | 0.07 |
| Uruguay | 435 | 660 | 750 | 1 117 | 200 | 262 | 218 | 485 | 323 | 621 | 966 | 849 | 598 | 2 216 | 0.17 |
| Ecuador | 994 | 867 | 900 | 900 | 578 | 578 | 600 | 579 | 332 | 372 | 300 | 300 | 300 | 400 | (0.21) |

## Table A6. North America

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Canada | 43 430 | 48 025 | 43 174 | 46 280 | 52 215 | 51 112 | 44 648 | 49 128 | 42 633 | 36 327 | 36 333 | 38 208 | 39 585 | 39 096 | (0.04) |
| United States of America | 74 632 | 74 279 | 73 359 | 76 829 | 60 218 | 46 548 | 36 826 | 43 579 | 48 642 | 54 378 | 42 650 | 36 688 | 33 490 | 38 349 | (0.14) |

## Table A7. Oceania

| | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | Trend |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Papua New Guinea | 13 500 | 14 500 | 14 500 | 14 500 | 14 500 | 14 700 | 14 570 | 13 300 | 13 500 | 13 500 | 14 000 | 13 500 | 13 590 | 13 580 | -0.01 |
| Fiji Islands | 2 378 | 2 383 | 3 117 | 4 748 | 4 444 | 4 054 | 4 502 | 4 040 | 4 084 | 2 907 | 2 964 | 3 586 | 3 034 | 4 325 | 0.02 |
| Australia | 2 567 | 2 054 | 1 721 | 1 966 | 2 003 | 2 000 | 2 544 | 2 600 | 3 757 | 3 211 | 584 | 1 724 | 1 766 | 1 544 | -0.03 |
| New Zealand | 400 | 400 | 400 | 489 | 684 | 833 | 703 | 1 097 | 1 252 | 1 160 | 1 100 | 1 115 | 1 079 | 1 025 | 0.17 |
| French Polynesia | - | - | - | - | - | - | 1 | - | - | 1 | - | - | - | 53 | 0.84 |
| Cook Islands | - | - | - | - | - | - | - | - | - | - | - | 10 | 10 | 10 | 0.73 |
| Micronesia, Fed. States of | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 0.1 |