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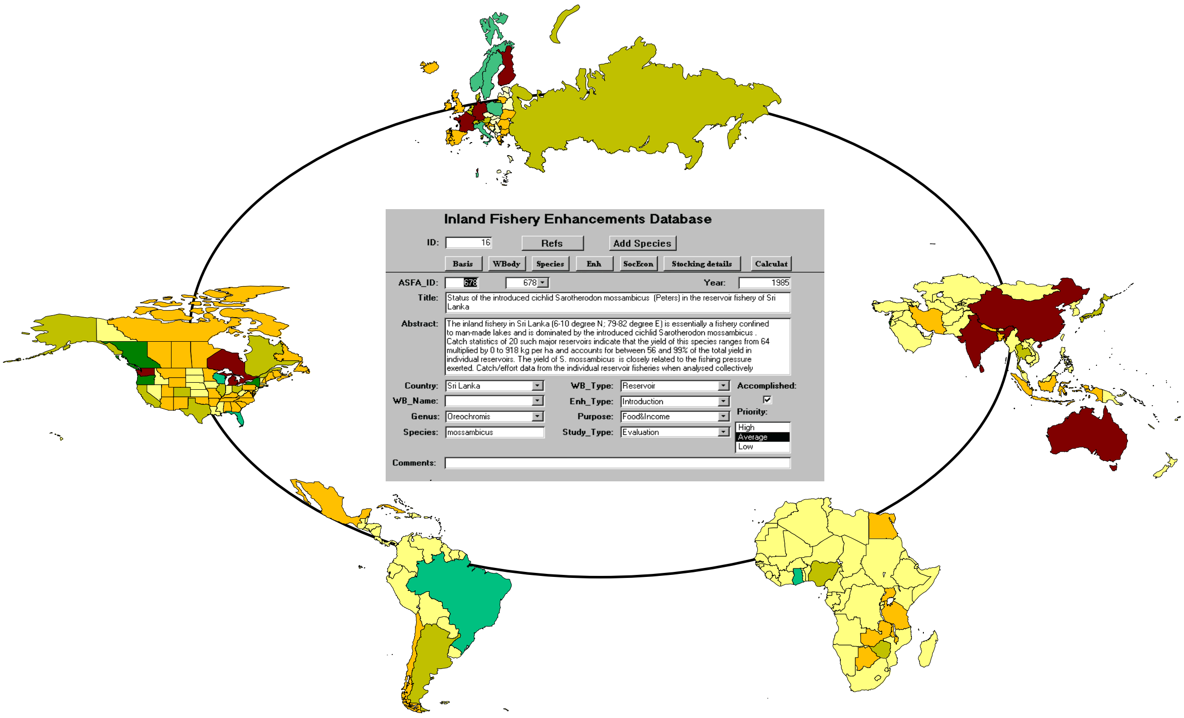
GLOBAL CHARACTERIZATION OF INLAND FISHERY ENHANCEMENTS AND ASSOCIATED ENVIRONMENTAL IMPACTS



Food and Agriculture Organization of the United Nations

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GLOBAL CHARACTERIZATION OF INLAND FISHERY ENHANCEMENTS AND ASSOCIATED ENVIRONMENTAL IMPACTS

by

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

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1999

PREPARATION OF THIS DOCUMENT

Mrs. Katrien M.M. de Pauw, Environmental Consultant, wrote section 5 on Environmental Impacts of Inland Fishery Enhancements. The remainder was written by Mr. Abraham F. Born, who was Associate Professional Officer (Inland Fisheries) in the Inland Water Resources and Aquaculture Service (FIRI) from January 1997 to November 1998.

Drs. James McDaid Kapetsky (Senior Fishery Resources Officer – Inland Fisheries), Kai Lorenzen (Renewable Resources Assessment Group, Imperial College, University of London) and Tomi Petr (Inland Fisheries Specialist) are gratefully acknowledged for their valuable comments. We would also like to thank Paul Siri (Bodega Marine Laboratory, University of California, Davis) for his role in initiating the study on environmental impacts of fishery enhancements.

George Ellis did the design and layout of the document.

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ABSTRACT

This paper summarizes the results of an effort to characterize inland fishery enhancements on a global scale. The basis for the characterization was an automated literature search in the Aquatic Sciences and Fisheries Abstracts (ASFA) for the years 1978-1997 with focus on introductions, stocking, environmental engineering and fertilization. The results were combined with information from the FAO Database on Introductions of Aquatic Species (DIAS) and the FAO Hatchery Production Database. Data were stored in a database for analysis and the results were linked to maps for a geographical presentation. An additional overview of the possible environmental impacts of inland fishery enhancements and associated prevention, mitigation and rehabilitation measures is also given.

Stocking and introductions are the most commonly used fishery enhancement techniques in inland water bodies and information was most abundant in North America, Europe, Asia and Oceania with fewer references for Africa and Latin America. Enhancement techniques to engineer the environment and to fertilize inland water bodies are less frequently used. Pre-intervention environmental assessments were found to be very scarce, but post-intervention studies were numerous, with a considerable amount of literature on the effects of predation by introduced species.

CONTENTS

1. SUMMARY

This paper summarizes the results of an effort to characterize inland fishery enhancements on a global scale. Fishery enhancements are techniques used to increase capture fisheries yields and include *inter alia* species introductions, stocking and engineering of the environment. The basis for the characterization was an automated literature search in the Aquatic Sciences and Fisheries Abstracts (ASFA) (1978-1997) with focus on introductions, stocking, environmental engineering and fertilization. The results were combined with information from the FAO Database on Introductions of Aquatic Species (DIAS) and the FAO Hatchery Production Database which were instrumental to fill gaps and provided ways for comparison with the ASFA results.

The results from the ASFA literature search were transferred to a database format and classification was done by country, enhancement type, enhancement purpose and species based on the contents of the abstracts. The database was analyzed with the use of queries and results were linked to maps for a geographical presentation.

The followed method for characterization of fishery enhancements was effective for classification of enhancement types, water body types and countries but it was less accurate for the identification of the purposes of enhancement.

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, construction of fish sanctuaries and spawning habitats, fencing and restoration of floodplain-river connections are used. Often these have 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 fertilization of inland water bodies as an enhancement technique is very scarce on a global scale, especially for the larger water bodies. Enhancement techniques within the regions of Africa, Latin America, Oceania and Asia are most diverse in Asia.

Introductions and stocking are most often carried out for production of food and for generating income. Of secondary importance is enhancement for recreational fisheries. Globally, introductions of Mozambique tilapia, common carp, rainbow trout, Nile tilapia and brook/sea trout have been important to enhance the production of fish as food and income source. Introductions of tilapias have been relatively successful in large water bodies due to the fact that this species establishes self-reproducing populations. 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 practices are least widespread in Africa compared to the other continents. Most information on stocking and introductions is related to North America and Europe, followed by Asia and Oceania. Relatively few references were found for Africa and Latin America.

An overview of the possible environmental impacts of inland fishery enhancements and associated prevention, mitigation and rehabilitation measures is given. Pre-intervention environmental assessments were found to be very scarce, but post-intervention studies were numerous, with a considerable amount of literature on the effects of predation by introduced species.

2. INTRODUCTION

Many inland capture fisheries that rely completely on the natural production capacity of the aquatic resource are exploited above or close to their sustainable maximum and as a result production levels of these kind of systems have reached a plateau. Increased pressure on fishery resources, environmental degradation of aquatic habitats and poor fisheries management has 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[1] and include various possibilities to intensify fishery production. Welcomme and Bartley (1998) made the following classification of enhancement types, ranked into practices from large to small size water bodies:

- Introduction of new species to exploit under-utilized parts of the food chain or habitats not colonized by the resident fauna;
- Stocking natural waters to improve recruitment, bias fish assemblage structure to favored species or maintain productive species that would not breed naturally in the system;
- Fertilization 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;
- 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;
- Aquaculture through management of the whole system as an intensive fish pond;
- Genetic modification of cultured species to increase growth, production, disease resistance and thermal tolerance of the stocked or cultured material.

Many fisheries in the world are nowadays enhanced in one way or another. For example various enhancement techniques have been used to develop or create new fisheries in Chinese reservoirs built primarily for non-fisheries purposes such as hydropower generation, flood control and irrigation. This has lead to a profound increase of reservoir fisheries production in China, where yields increased from 180 kg/ha in 1957 to 650 kg/ha in 1996 (Weimin, in press). Stocking is also commonly used in lakes fisheries management in Finland where brown trout *(Salmo trutta fario)* has been stocked extensively and the majority of yields rely on regular stocking of this species (Vehanen and Aspi 1996). Globally, there exist a large number of water bodies that offer possibilities to increase fisheries yields in the near future, with introductions of new species and continuous stocking of farm based juveniles as the most likely techniques (Dunn 1994). Though fishery enhancements are likely to expand only at a moderate pace (FAO/Department for International Development of the United Kingdom 1997), the rational enhancement of the available aquatic resources for fisheries production

[1] To date no suitable translation for this term is available in French or Spanish languages. The term fishery intensification can be used in these instances until a suitable wording has been developed.

offers a useful tool for improvement of food security and poverty alleviation in many areas of the world.

The global interest in fishery enhancement was clearly shown in the outcomes of the Japan/FAO Conference on Sustainable Contribution to Food Security, Kyoto, Japan, December 1995 where a rapid transfer of know-how in enhancements was included in the Plan of Action (see ref. FAO/Kyoto 1995). Also, four specific avenues to the development of enhancements were mentioned in the Kyoto Declaration, namely: stocking and restocking, assisting fishers to organize themselves, promoting community management schemes and establishing user rights in open access. The Expert Consultation on Inland Fishery Enhancement, held in Dhaka Bangladesh, 7-11 April 1997, also recognized the importance of integrating technical, socio-economical and cultural factors in the implementation of fishery enhancement programs (FAO/Department for International Development of the United Kingdom 1997).

For some time enhancement of inland fishery production has been considered a priority area by the Inland Water Resources and Aquaculture Service of FAO. The present study was performed as a first step to a global evaluation of benefits, impacts and prospects for inland fisheries enhancements. Its aim was to characterize enhancements by type, by water body, by target species and by location and country. The basis for this characterization was a structured literature search in the Aquatic Sciences and Fisheries Abstracts (ASFA).

Emphasis was put on regions where Low Income and Food Deficient Countries (LIFDCs) exist and hence the searches were initially performed for Africa, Asia, Latin America[2] and Oceania. The USA, Canada and Europe were later on included, using a slightly different approach.

Because of the concerns associated with enhancements, especially with respect to introductions of exotic species, an overview of the possible environmental impacts of inland fishery enhancements and associated prevention, mitigation and rehabilitation measures was prepared by environmental consultant Mrs. K.M.M. de Pauw (Chapter 5).

A description of the methods used, the results of the analysis, and a discussion of the followed methods is given in the next chapters. The analysis was primarily performed with the idea to provide an overview of inland fisheries enhancements and to evaluate the applied method.

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[2] The regions South America and Central America excluding USA and Canada are referred to as Latin America.

3. METHODS USED TO CHARACTERIZE INLAND FISHERY ENHANCEMENTS

3.1 Literature search in the Aquatic Sciences and Fisheries Abstracts (ASFA)

The basis for this characterization was a structured literature search in the Aquatic Sciences & Fisheries Abstracts (ASFA). ASFA covers all aspects of marine, brackish, and freshwater environments, including biology, ecology, fisheries and aquaculture. Citations are drawn from a variety of sources, including journal articles, conference papers, books, monographs, theses, technical reports, and non-conventional literature. Over 40 languages are included. Information is supplied by the Aquatic Sciences and Fisheries Information System and updated by research centers throughout the world.

WINSPIRS PC software was used to search the ASFA database. The search profiles were initially developed for the tropical regions of Africa, Asia, Latin America and Oceania. Those for North America and Europe were included later. Introductions, stocking, environmental engineering and fertilization were included as enhancement types with specific focus on inland water environments (Table 1).

Table 1: Overview of search profiles

Category	Search Profile
Region	Africa
	Asia
	Europe
	North America
	Central America
	South America
	Oceania
Enhancement type	Introductions
	Stocking
	Engineering of the environment
	Fertilization

The more intensive forms of enhancements such as aquaculture, cage culture and genetic improvement of cultured species were not specifically included in the searches. References related to the development of artificial faunas of selected species, which are basically a result of stocking and introduction, were mostly covered by the stocking and introduction profiles. Search profiles were first created for the various regions and enhancement types and they were later on combined (e.g. stocking in Asia, introductions in North America etc.). The searches were done for the period 1/1978 – 9/1996 for stocking, 1/1978 – 12/1996 for introductions and 1/1978 – 6/1997 for engineering and fertilization. Listings of the search profiles are given in Annex 1. The time required for the development of the search profiles was approximately one month. The selection of appropriate key terms was most time consuming.

3.2 Processing of downloaded search profiles

The search results were downloaded from ASFA within the WINSPIRS menu in a text format including the fields: Title, Author, Publication Year, Source, Language, Abstract, Descriptor and ASFA Reference Number. A macro was written to organize the downloaded records into a Microsoft Excel spreadsheet (required time: 1 week). The spreadsheet was later on imported into a Microsoft ACCESS database. Detailed descriptions of the method and Visual Basic listings of the macros are given in Annex 2. It takes about 30 minutes to arrange about 300 references into a spreadsheet format. The macro requires a uniform format, i.e. all fields (title, author etc.) should be in the search results. Because fields are sometimes missing a check is required (missing fields need to be inserted) prior to running the macro. This is the most time consuming part.

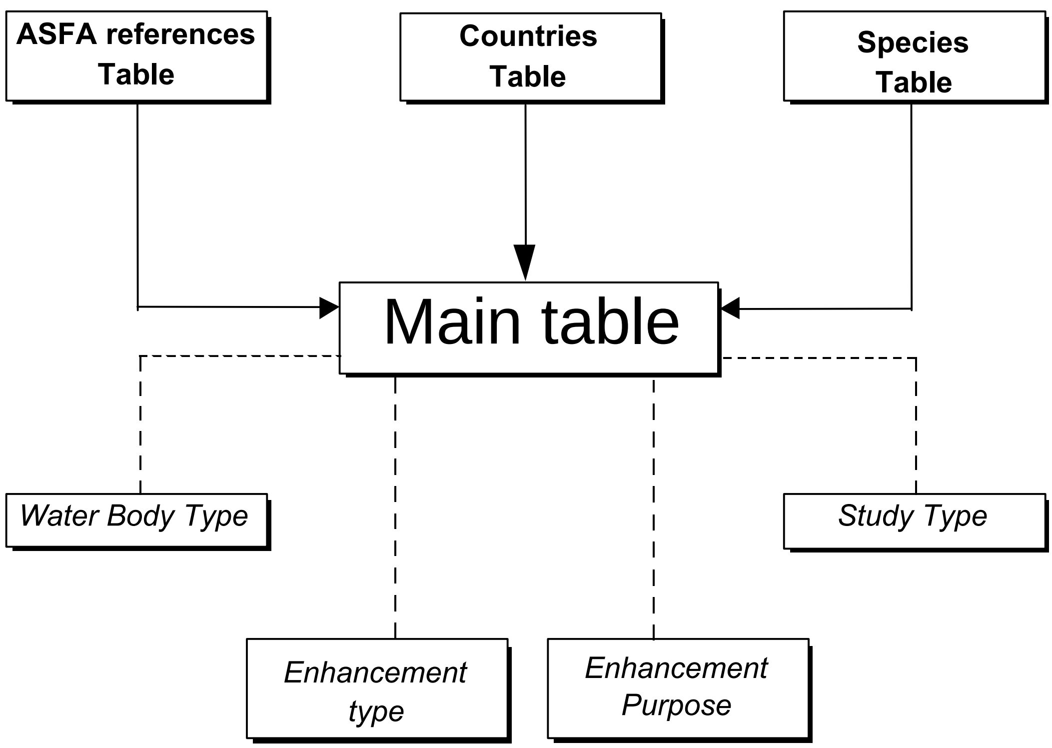
3.3 Inland Fishery Enhancements Database (IFED): Asia, Oceania, Africa and Latin America

A database was constructed to be able to prepare quick overviews of enhancement information. For this purpose the downloaded references were imported into a Microsoft ACCESS format and linked to other tables with species, countries etc. (see next paragraph). Queries were designed to process the enhancement characteristics and to prepare tables that were later on used to map the information.

3.3.1 General layout

The database is structured as a relational database (Figure 1). The three tables on top are linked to the main table whereas the four at the bottom are related to the main table via check boxes which contain a pre-set list of entities to be entered in the database. This ensures consistency of the variables used in the various data fields. The contents of each table are described in the following paragraphs.

Figure 1: General Layout of Inland Fishery Enhancements Database



3.3.2 Main table

The indicators used in the main table are presented in Table 2. The fields indicated with an asterisk were not used in the analysis because these must be worked out further and defined. They can be used for further classification of enhancements.

Table 2: Main table

Columns	Type	Size	Description
ID	Number (Long)	4	ID
ASFA_ID	Number (Long)	4	ASFA literature reference ID
Country_ID	Number (Long)	4	Country ID
WB_Type	Text	50	Water body type: lake, reservoir, river etc.
WB_Name	Text	50	Name
Species_ID	Number (Long)	4	Species ID
Enh_Type	Text	50	Enhancement type: stocking, introduction, environmental engineering
Enh_Purpose	Text	50	Purpose/reason: food, income, mitigation etc.
Study_Type*	Text	50	Study type: impact assessment, experiment etc.
Enh_Success*	Text	50	Successful?
Comments	Memo	-	Comments
Accomplished*	Yes/No	-	Actually carried out or theoretical study
Status*	Text	50	Ongoing/finished
Relevance	Number	8	Dummy variable

* Not used in analysis; to be developed

3.3.3 References

The construction of this table (Table 3) has already been described in the foregoing paragraphs. The structure of this table is equal to the Excel worksheet (see section 3.2). The fields Excel_ID and Excel_Check refer to this. Reference details, not listed in this table, can be looked up in the original ASFA data set through the unique ASFA_ID of each reference. This may be necessary when source data are not complete which is sometimes the case for conference proceedings. This table contains 1263 references. Of these, 496 have been used in the database.

Table 3: ASFA References table

Name	Type	Size	Description
Excel_ID	Number	8	Reference to excel spreadsheet
Title	Text	150	Title
Author	Text	150	Authors
Source	Text	150	Source
Year	Number	8	Year of publication
Language	Text	50	Language
Descriptor	Text	150	ASFA descriptors
ASFA_no	Number	8	ASFA reference number
File	Text	11	Downloaded filename (example: enhasst.txt)
Excel_Check	Number	8	Check for doubles in Excel
Read	Text	10	Indicate if read and when
Remarks	Memo	-	ASFA abstract
ASFA_ID	Number (long)	4	Primary key/reference
Remarks2	Memo	-	Additional remarks

3.3.4 Species

A total of 114 different species and species groups are entered in the database. Where species names were not indicated in the abstracts, or when a group of species was used, these were entered as species groups in the table. The following groups/names were used:

- Carps
- Indian major carps
- Chinese carps
- Indian and Chinese carps
- Tilapias
- Crayfish

The table is based on the species list in FAO's Database on Introductions of Aquatic Species. New species were added where required

Table 4: Species table

Name	Type	Size	Description
Species_ID	Number (long)	4	Species reference number
Genus	Text	23	Genus
Species	Text	30	Species
Family	Text	50	Family
Taxon	Text	20	Taxon
Common name	Text	250	Common name
Marine	Yes/No	-	Marine
Brackish water	Yes/No	-	Brackish water
Freshwater	Yes/No	-	Freshwater

3.3.5 Countries

The FAO official country list as used in the Database on Introductions of Aquatic Species (version 1997) was used to construct this table.

Table 5: Country table

Name	Type	Size	Description
Country_ID	Number (long)	4	Country reference
Country	Text	35	Country name
Continent	Text	30	Continent name (FAO classification)

3.3.6 Water bodies

The water body types that were included along with their definitions and descriptions are given in Table 6.

Table 6: Water body types

Water Body Type	Description	# Entries
Coastal lagoon	Coastal semi-enclosed water bodies with an open connection to the sea.	20
Floodplain lake	Perennial lakes associated with floodplains.	3
Floodplain pool	Bodies of water of some depth and slight to moderate vegetation cover which become isolated and have a tendency to dry out in the dry season and re-establish connection to the river channel in the wet season(s) (Welcomme 1985).	5
Natural lake	Bodies of water of some depth and slight to moderate vegetation cover which persist relatively unchanged over a number of years (Welcomme 1985).	123
Not specified		171
Oxbow lake	Former river channel, now disconnected from main river.	1
Pond	Small freshwater bodies, usually man-made, where aquaculture is possible.	1
Reservoir	Artificial lake used for drinking water supply, irrigation, power generation, power plant cooling and/or flood control.	187
River	Linear systems which serve to evacuate water falling on the continental masses towards the oceans (Welcomme 1985).	74
Swamp	Depression wetlands whose soil remains saturated or more or less permanently covered with shallow waters and which support characteristic growths of vegetation, which dominate the environment. (Welcomme 1985).	2
SWBs	Small water bodies like village tanks or ponds, irrigation ponds.	10
Various	Various undefined water bodies mentioned in reference.	58

3.3.7 Enhancement type

The enhancement types that were used for characterization are summarized in Table 7. As mentioned before, this study was focussed on introductions, stocking, environmental engineering and fertilization. Other enhancement types were classified but not used in further analysis because these are relatively under-represented which makes it difficult to create a reliable overview. They can however be used as a start for further characterization.

Table 7: Enhancement types

Enhancement type	Description	# Entries
Aquaculture	Management of the system as an intensive fish pond.	3
Artificial fauna	Creating fish assemblages of selected species to optimize use of food resources, reproduction habitat.	2
Cage culture	Aquaculture in net cages and pens.	15
Environmental engineering	Improve levels of reproduction, shelter, food bodies and vital habitat through modification of the environment.	11
FADs	Fish attracting devices such as brush parks.	13
Fertilization	Increase of the carrying capacity of the water body to sustain more fish, reduce mortality and enhance growth through elimination of density dependent effects.	19
Genetic modification	Genetic modification of fish species for stocking and culture to improve growth, reproduction, disease resistance, thermal tolerance.	2
Introduction	Any species (exotic and non-indigenous) intentionally or accidentally transported and released by man into an environment outside its present range (Welcomme 1988). An Introduction is carried out at a certain point in time, not repeatedly or regularly as is stocking, to create a new sustainable fishery with the aim to establish a self-reproducing population of the introduced species.	306
Modification of water body	Create confined water bodies to improve management and control the flow of nutrients.	0
Not specified		14
Reserve	Creating fish sanctuaries to avoid recruitment over-fishing.	4
Species elimination	Elimination of unwanted species that compete or predate upon target species.	4
Stocking	Repeated release of organisms into an ecosystem from one external ecosystem for mitigation, conservation, restoration or compensation of over-fished stocks and to enhance stocks that do not reproduce naturally in the target water body. The organisms may be native or exotic to the ecosystem (Cowx 1998).	215
Translocation	Any species (includes transplanted species) intentionally or accidentally transported and released within its present range (Welcomme 1988).	16
Various	Combinations of enhancements.	23

3.3.8 Enhancement purpose

The various purposes of enhancements are given in Table 8.

Table 8: Purpose of enhancements

Purpose	Description	# Entries
Accidental	Accidental introduction	5
Aquaculture	For aquaculture	1
Conservation	Conservation of species threatened with extinction	9
Fill niche	Fill a vacant niche	4
Food&Income	Production of food and creating income	191
Mit_fish	Mitigation in response to over-fishing	1
Mit_hab	Mitigation in response to habitat degradation	10
Not Specified		357
Plant&Animal Control	Control of aquatic weeds, unwanted organisms	20
Recreation	Sports fisheries	43
Resettlement	Resettlement of communities around the water body	1
Restoration	Restoration of stocks after a limiting factor has been removed	8
Various		4

3.3.9 Study type

The types of study in the references were classified as shown in Table 9.

Table 9: Study types

Study Type	Description	# Entries
Environmental assessment	Study on the effects of enhancements on the environment	76
Evaluation	Evaluation of an enhancement	313
Experimental	Experimental research	51
Genetic assessment	Study on the effects of enhancements on population genetics	5
Model	Mathematical models relevant to enhancements	22
Project	A project related to enhancements	15
Proposal	A proposal to enhance fisheries (not carried out yet)	22
Review	A review/overview of enhancements	241
SocEcon	Socio-economic aspects of enhancements	21

3.4 Inland Fishery Enhancements Database (IFED): Europe and North America

The characterization of fishery enhancements in Europe and North America was focussed on stocking, introductions and translocations. The large number of references (1864 for North America and 1089 for Europe) called for a fast method of selection and for this purpose the references with key terms: species-introductions, stocking-organisms, country names, lake or L., river or R., reservoir and impoundment were selected. The species that were referred to in the references were counted with a “COUNTIF” function that evaluated a species list

Table 10: Layout and number of entries of the Inland fishery Enhancements Database for Europe and North America

Field	Description	# Entries Europe	# Entries North America
TI	Title	1098	1864
AU	Authors	1084	1805
SO	Source	1098	1864
PY	Year of publication	1095	1852
LA	Language	1098	1864
AB	Abstract	1058	1851
DE	ASFA descriptors	1097	1864
AN	ASFA reference number	1098	1864
Country	Country Name	1098	1864
EnhType	Enhancement Type	697	1634
Reason	Purpose of enhancement	43	624
Study*	Study type	77	272
Continent	Continent	1098	1864
WB	Water body type	670	1230
WB name	Water body name	12	349
Species	Species name	49	549
State	State (only for USA and Canada)	0	1515

* Not used in the analysis

(including all species listed in Fishbase and the FAO's Database on Introductions of Aquatic Species) with the species names in the descriptor fields of the references. The layout of the database is given in Table 10.

3.5 FAO Database on Introductions of Aquatic Species (DIAS)

The FAO Database on Introductions of Aquatic Species (DIAS)[3] was used as an additional source of information. This database contains information about species, country, the reason for introduction and whether the introduced species has established itself in the wild; as well as other information (for a detailed review of introductions and analysis of these data see Welcomme 1988). These data were used to prepare maps of the number of freshwater species introduced per country and to list the most important species that were established in the wild. Freshwater species were defined as those species that live in freshwater environments (excluding the species that do not exist in fresh water). This includes anadromous and catadromous species and aquatic species that exist in all environments (e.g. some tilapia species). The database provides information on the living environment for each species.

3.6 FAO Hatchery Production Database

Hatchery production data are reported to FAO by its member countries based on a questionnaire for reporting statistics on aquaculture. Hatchery output is recorded as stocking "to a controlled environment" (e.g. for aquaculture) or stocking "to the wild" (e.g. stock enhancement of open waters). For the purpose of this study, data reported as stocking "to the wild" was used. These data were used to create maps of the number of species per country that are produced in hatcheries for stocking to the wild and to prepare a list of most important species in terms of numbers produced for each region. The period covered is 1984-1995.

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[3] See http://www.fao.org/WAICENT/FAOINFO/FISHERY/statist/fisoft/dias/index.htm

4. GLOBAL OVERVIEW OF ENHANCEMENT PRACTICES

In the following sections an overview of the different enhancements is given for the various regions: Asia & Oceania, Africa and Latin America, North America and Europe. It should be noted that the results are based on information from ASFA searches specifically for introductions, translocations, stocking, environmental engineering and fertilization. For North America and Europe the focus was only on introductions, translocations and stocking. This means that the other enhancement types are probably under-represented and the number of references could probably be increased with specific searches for these enhancement types.

4.1 Asia & Oceania

4.1.1 Inland fishery enhancements

Figure 2 gives an overview of the various enhancement types in Asia and Oceania and their subsequent number of entries in the Inland Fishery Enhancement Database. Only seven entries refer to engineering of the environment and only one to fertilization. Most entries describe introductions and stocking.

The majority of enhancements (i.e. mainly introductions and stocking) are targeted at reservoirs, rivers and lakes (Figure 3). Only a few references were found that described enhancements in smaller water bodies (SWBs and ponds) despite their abundance in the region. Sugunan (1997) reviewed fisheries management in small water bodies in India, Thailand and Sri Lanka. In Thailand most of the published accounts concern large reservoirs, which is in line with the above findings. Information about the enhancement of floodplain habitats is also scarce, though floodplain pools have been stocked with fingerlings in Bangladesh. The project documents do however not appear in the search.

Figure 2: Enhancement types for Asia and Oceania

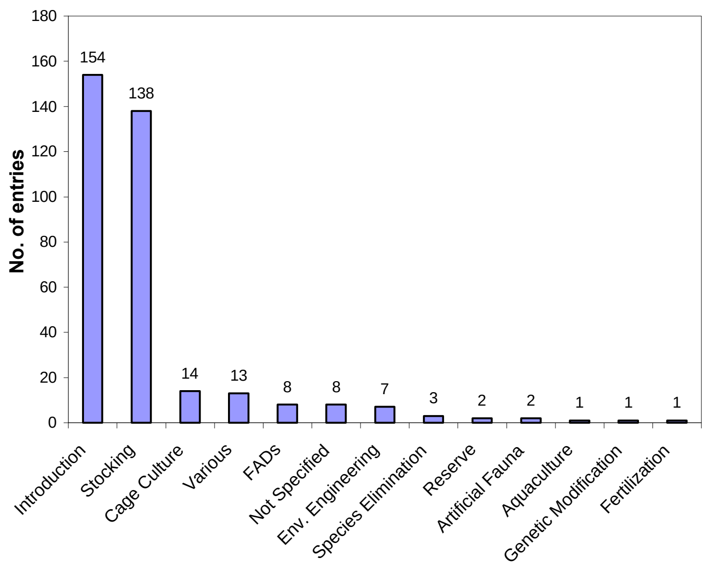
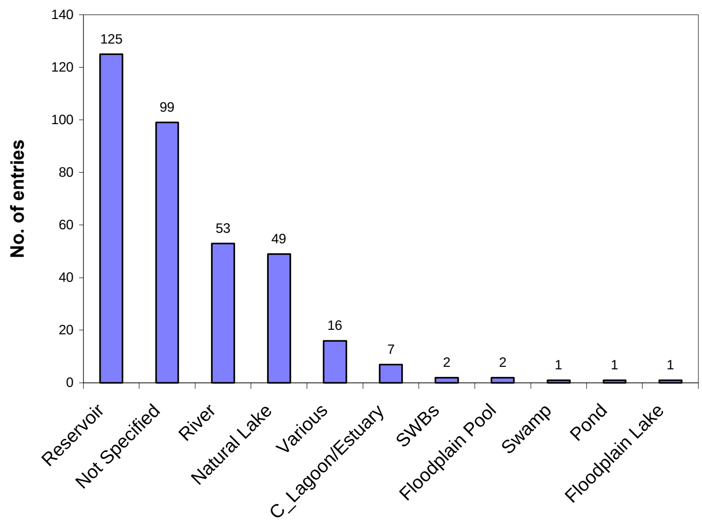


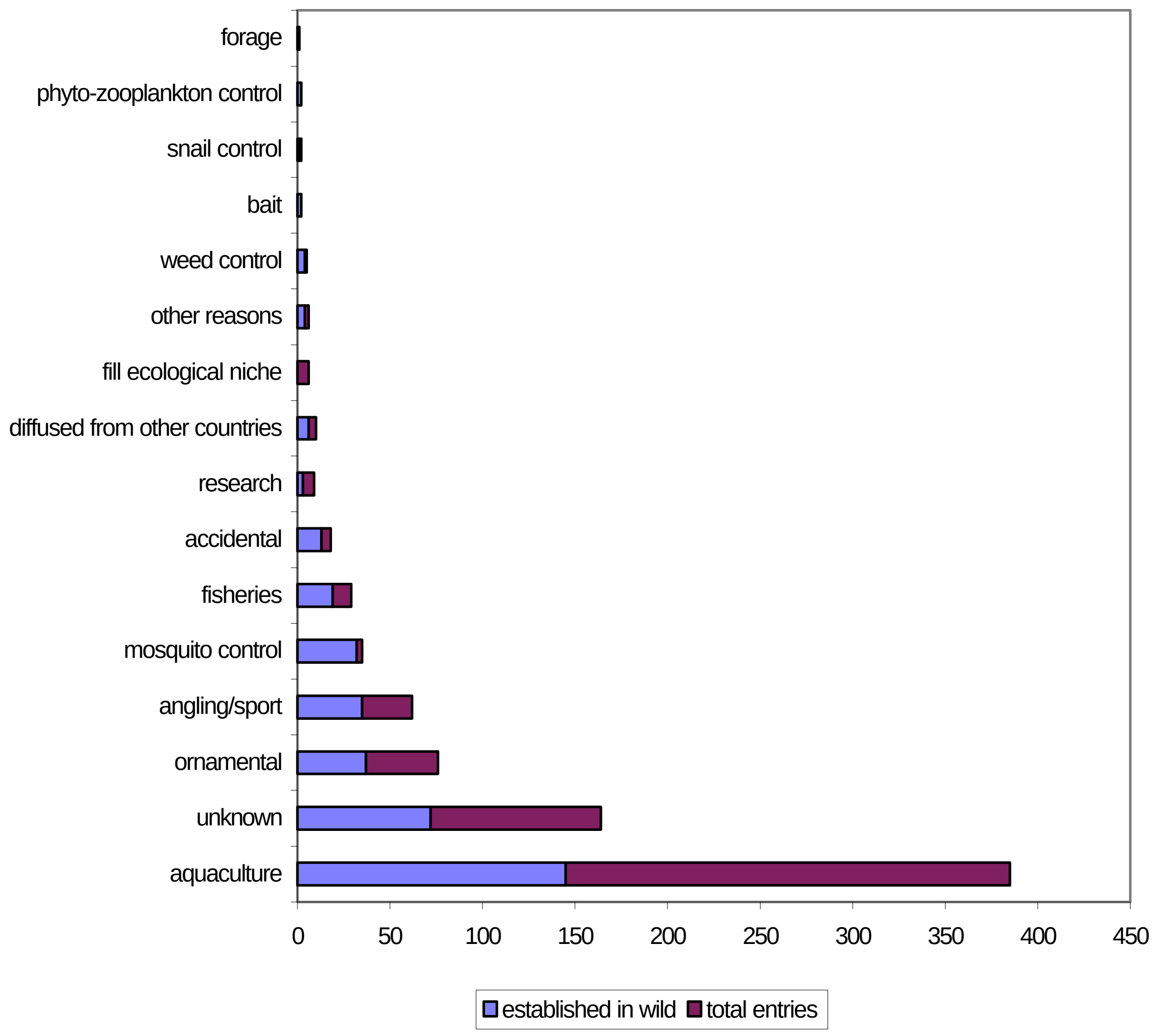
Figure 3: Water bodies distribution for inland fishery enhancement in Asia and Oceania



4.1.2 Introductions

Welcomme (1988) lists 185 introductions of aquatic species in Asia/USSR and 160 for Oceania. The various reasons for introductions in Asia and Oceania are shown in Figure 4. The majority of species were introduced for aquaculture but some of these species became established in open waters, as indicated in the figure. For example, the tilapia *Oreochromus mossambicus* was initially introduced into Sri Lanka for aquaculture purposes, but it has become the main species in reservoir capture fisheries (de Silva 1988). About half (46%) of the species that were introduced to the region resulted in successfully established populations.[4]

Figure 4: Reasons for introduction of freshwater species in Asia and Oceania

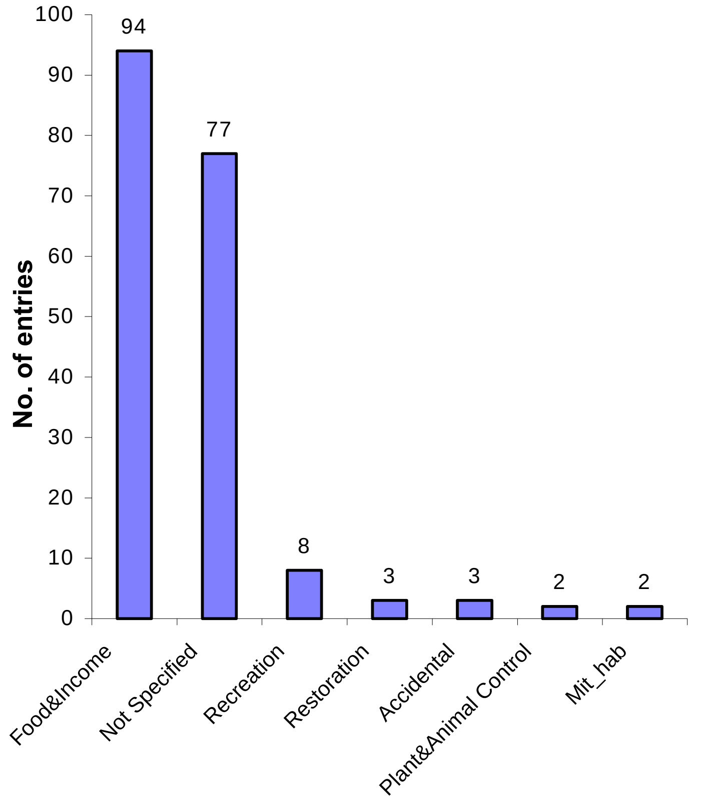


(*Source*: FAO Database on Introductions of Aquatic Species (DIAS))

[4] The overall success of an introduction depends not only on the successful colonization of the species in its new environment, but also on the ecological impacts for the native aquatic communities and the possible sociological effects for the people that depend on the fisheries in the system. The fact that an introduced species has established itself does not automatically mean that the introduction was successful.

Enhancements in Asia and Oceania are primarily carried out to produce food and create income. Recreational fisheries are of secondary importance (Figure 5). The majority of introductions in the region were done with the aim to produce food through aquaculture.

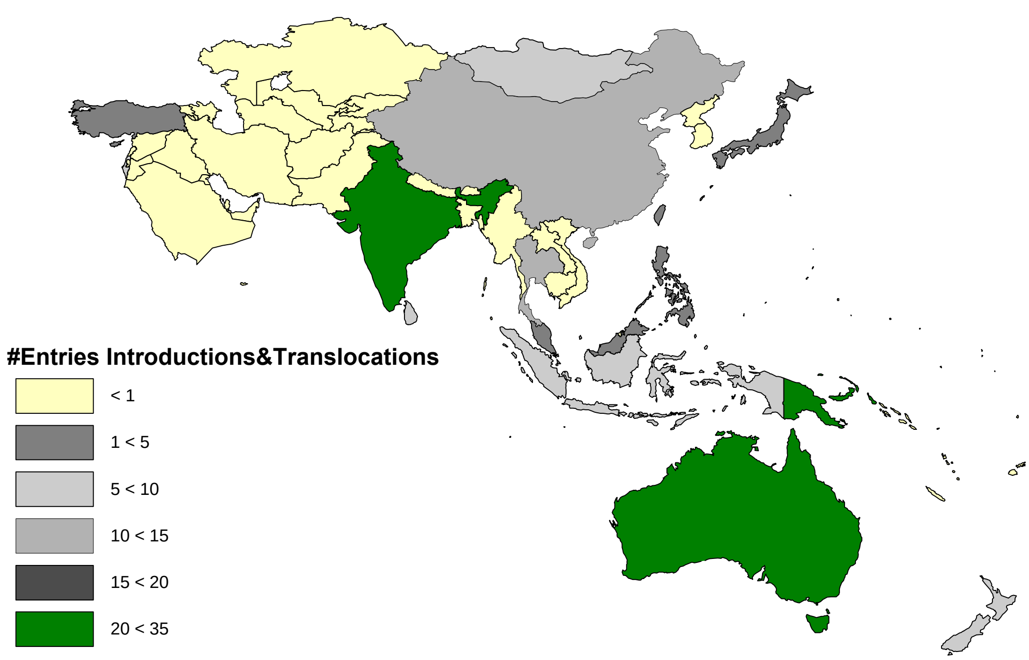
Figure 5: Main purposes of introductions in Asia and Oceania



The available information for each country in the region is given in Figure 6. For comparison, the number of freshwater species introductions is shown in Figure 7. Both maps indicate that introductions are relatively important in Australia, China, India, Malaysia, Papua New Guinea and Thailand. The relative importance of the first three countries can be partly explained by their large size.

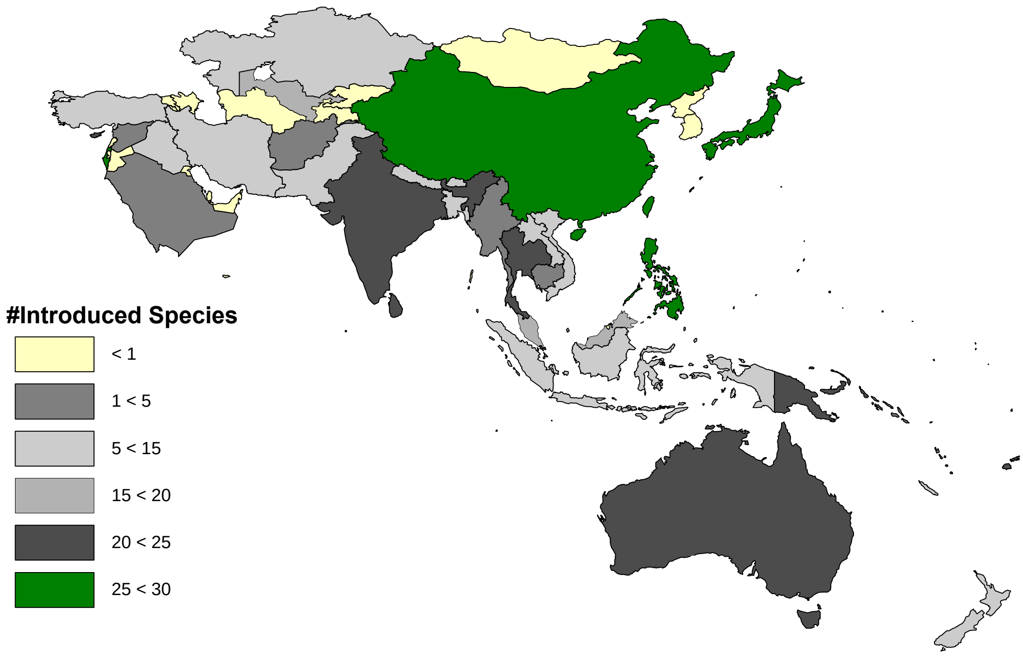
Translocations have been one of the major measures for enhancement of inland water bodies in Australia, mainly for the purpose of recreational fisheries (Petr 1998). Indigenous angling species like Australian bass (*Macquaria novemaculeata*), golden perch (*Macquaria ambigua*) etc. have been released in farm dams, but these

Figure 6: Geographical distribution of information on introductions and translocations in Asia and Oceania



often cannot reproduce in their new environments and therefore need continuous re-stocking. Furthermore, exotic species like common carp (*Cyprinus carpio*), European perch (*Perca fluviatilis*) and rainbow trout (*Onchorhyncus mykiss*) were introduced into rivers and impoundments in Australia.

Figure 7: Distribution of species introductions in Asia and Oceania



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

Introduction and translocations of exotic and indigenous species have been carried out in the last 3 decades in China. To date, about 50 different species have been introduced in China, which include tilapia, rainbow trout, and Indian carps, freshwater giant prawn (*Macrobrachium rosenbergii*), European eel (*Anguilla anguilla*) and others (Weimin in press). Among the introduced species, white crucian carp *Carassius curvierri* has been relatively successful to form populations especially in lakes. Even better results have been obtained with translocations of indigenous species. Wuchang fish (*Megalobrama amblycephala*) was the first native fish that was transplanted to lakes and reservoirs and that successfully established natural populations (Weimin in press). Also, transplanted small-scale yellowfin (*Plagigonathops microlepis*) and freshwater yellowtail (*Xenocypris davidi*) significantly enhanced fish production of many reservoirs in China (Lu 1992). Introductions of freshwater smelt *Hypomesus olidus* and whitefish (*Coregonus* sp.) are also reported in the colder regions (Lu 1992). Most recently icefish (*Neosalanx taihuensis* and *Protosanlanx hyalocranius*) was very successfully transplanted to various provinces of China. By 1997, production of icefish reached 10,000 metric tons, of which transplanted icefish contributed as much as 8,000 metric tons (Weimin in press).

Several species have been introduced to India, most notably, Mozambique tilapia (*Oreochromis mossambicus*), common carp, silver carp (*Hypopthalmichthys molitrix*) and grass carp (*Ctenopharyngodon idella*) (Sugunan 1995). Common carp was not successfully introduced, not being able to establish itself in the larger reservoirs and it has had a negative impact on the local fish communities in several instances (Sugunan 1995). Mozambique tilapia established itself successfully in the larger reservoirs as it did in Sri Lanka (de Silva 1988).

Ang *et al.* (1989) describes the introduction of 12 exotic species in Malaysia of which snake-skin gourami (*Trichogaster pectoralis*), silver barb (*Puntius gonionotus*), tilapia and the cat-fish (*Clarias macrocephalus*) successfully established breeding populations. Introduced fishes contribute 72% of the total freshwater capture fisheries production in Malaysia. Many introductions into Malaysia are associated with aquaculture and ornamental fish trade (Ali 1998).

A considerable amount of information in Papua New Guinea has been made available through an effort to introduce and stock the Sepik/Ramu basin to enhance the nutritional status of its inhabitants, especially in the high altitude regions. The project released a total of 8 species into rivers and lakes of which three species (*Tilapia rendallii*, *Puntius gonionotus* and *Prochilodus margravii*) have successfully established populations so far (FAO 1997b).

Various exotic species have been introduced into reservoirs in Thailand mainly for food production, among them Common carp, Mozambique tilapia and Chinese and Indian carps. The yields of Nile tilapia (O*reochromis niloticus*) and bighead carp (*Aristichthys nobilis*) were successfully increased in several reservoirs (Baluyut 1983). For the Mekong region (Laos, Cambodia, Vietnam and Thailand) Bernascek (1997) concludes that introductions of Nile tilapia into larger reservoirs were generally successful whereas non-indigenous Indian and Chinese carp generally failed to establish itself, common carp being an exception.

Though few references could be found on introductions in Japan and the Philippines (Figure 6), the DIAS shows that 54 and 39 freshwater species were respectively introduced in these countries. In Japan, the majority of freshwater species were introduced for aquaculture and only four species for fisheries purposes; two sturgeons, *Coregonus clupeaformis* and grass carp of which only the latter established itself in open waters. In the Philippines, the fish fauna of lakes and reservoirs has been enriched by the introduction of various species, most important milkfish (*Chanos chanos*), tilapia, common carp and the Indian carp (*Labeo rohita*), gourami and Java barb (*Puntius javanicus*) (Baluyut 1983).

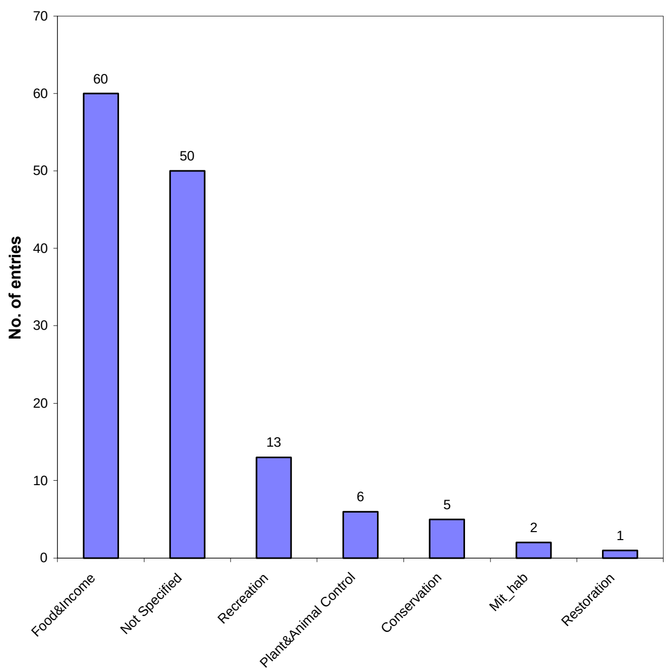
Information on species level is presented in Table 11. *O. mossambicus* and *C. carpio* are referred to relatively often. These species were successful in colonizing inland waters in Asia and Oceania. The important species for introductions in Asia and Oceania belong mainly to tilapias and cyprinids.

Table 11: Important introduced species with reference to establishment into the wild for Asia and Oceania

Most referred introduced species*			Established in wild**		
Genus	Species	# Entries	Genus	Species	# Countries
Oreochromis	*niloticus*	24	*Oreochromis*	*mossambicus*	37
Cyprinus	*carpio*	15	*Cyprinus*	*carpio*	24
Labeo	*rohita*	15	*Gambusia*	*affinis*	21
Oreochromis	*mossambicus*	12	*Poecilia*	*reticulata*	16
Hypophthalmichthys	*molitrix*	6	*Carassius*	*auratus*	12
Ctenopharyngodon	*idella*	6	*Oncorhynchus*	*mykiss*	11
Coregonus	*peled*	6	*Hypophthalmichthys*	*molitrix*	10
Aristichthys	*nobilis*	6	*Oreochromis*	*niloticus*	9
Oreochromis	*spp.*	4	*Salmo*	*trutta*	7
Oncorhynchus	*mykiss*	4	*Trichogaster*	*pectoralis*	7
Tilapia	*rendalli*	3	*Xiphophorus*	*hellerii*	7
Macrobrachium	*rosenbergii*	3	*Poecilia*	*latipinna*	6
Osphronemus	*goramy*	2	*Puntius*	*gonionotus*	6
Clupeichthys	*aesarnensis*	2	*Micropterus*	*salmoides*	6
Cirrhinus	*mrigala*	2	*Clarias*	*batrachus*	5
Chinese carps		2	*Oreochromis*	*aureus*	5
Crayfish		2	*Tinca*	*tinca*	5
Salmo	*trutta*	2	*Procambarus*	*clarkii*	5
Salmo	*trutta fario*	2	*Channa*	*striata*	5
Lates	*niloticus*	2	*Carassius*	*carassius*	5
Cirrhina	*molitorella*	2	*Ctenopharyngodon*	*idella*	5

Source: Inland Fishery Enhancements Database
FAO Database on Introductions of Aquatic Species

Figure 8: Main purposes of stocking in Asia and Oceania



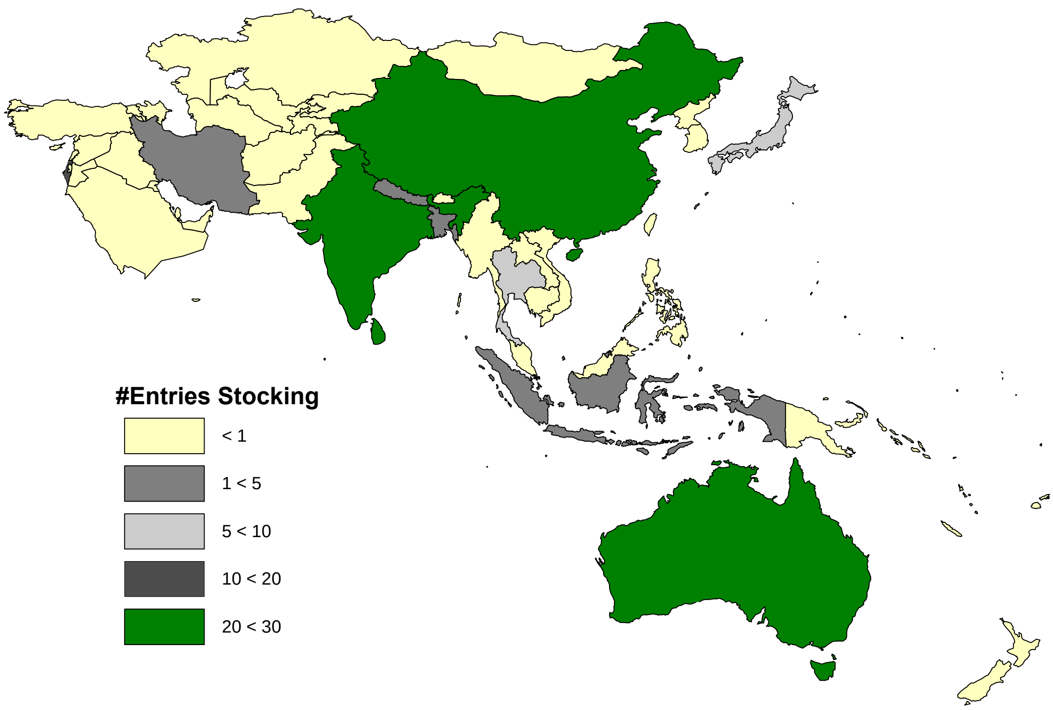
4.1.3 Stocking

As for introductions, the main aim for stocking of inland waters in Asia and Oceania is production of food and generating income, with recreational fisheries in the second place (Figure 8).

The geographical distribution of the available information on stocking in the regions is presented in Figure 9 (on the following page). Information provided for India, Sri Lanka, China and Australia, and to a lesser extent Japan and Thailand was most abundant as can be seen in the figure.

Stocking of reservoirs has been an important policy in India, where yields in some reservoirs increased ten-fold as a result of extensive stocking (Sugunan 1995). However, in general, most of the reservoirs remain unstocked due to a shortage of stocking material (Sugunan 1997). The main species stocked are the Indian major carps, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). Other carp species such as common carp and grass carp have been stocked on specific occasions. Stocking of *O. mossambicus* is not favored due to its rapid proliferation although it has performed well in some instances (Sugunan 1997). For the higher altitudes, masheer (*Tor putitora*), *Labeo dero*, silver carp, tench (*Tinca tinca*) and *Carassius carrassius* are promoted. Masheers have been stocked in response to declining stocks and for sport fisheries. Stocking of small reservoirs (< 1000 ha) has been much more effective than for larger reservoirs. Especially indigenous Indian carps have been relatively successful (Sugunan 1997). This observation was also made in Sri Lanka where the repeated stocking of carps in larger perennial reservoirs did not have a positive impact on fish production (De Silva 1988) but stocking of smaller seasonal reservoirs yielded some good results (Amarasinghe 1998).

Figure 9: Geographical distribution of database entries on stocking in Asia and Oceania



Stocking is widely applied in China. Most Chinese inland waters, especially reservoirs, have been stocked with silver carp and bighead carp which normally make up 60-80% of the stocked species (Weimin in press, Li and Wu 1995). These two species account for the major production in Chinese freshwater fisheries (Lu 1992). Common carp, crucian carp (*Carassius auratus*), Wuchang fish, mud carp (*Cirrhinusa molitorella*) and grass carp are additionally stocked, though post-impoundment studies have shown that several of these species can reproduce in the reservoirs and therefore need not to be stocked (Lu 1986). The stocking ratios of the different species depend on the composition of natural food items in the water. The yields of many newly built reservoirs have increased from 180 kg/ha in 1957 to 650 kg/ha in 1996, partly because of stocking of open waters and partly because of other enhancement techniques (e.g. cage culture). The exact benefits from stocking are difficult to estimate because Chinese Fishery Statistics do not specifically report yields from stocking.

In Queensland, Australia, Golden perch (*Macquaria ambigua*), silver perch (*Bidyanus bidyanus*) and Australian bass are the main species stocked into impoundments to establish and maintain recreational fisheries (Petr 1998). Rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta fario*) are also stocked. In addition, the endangered species trout cod (*Maccullochella macquariensis*) and eastern freshwater cod (*Maccullochella ikei*) have been produced in hatcheries and stocked into waters where they had become extinct (Rowland 1995). In Victoria, Murray cod and trout cod are stocked for conservation and golden perch, rainbow trout, brown trout and chinook salmon (*Oncorhynchus tshawytscha*) for recreational purposes.[5] In Tasmania, rainbow trout are frequently stocked in impoundments close to population centers (Petr 1998).

In Thailand, stocking programs have been carried out since 1950 with gourami (*T. pectoralis*) and Mozambique tilapia released into swamps. At present, stocking is more focused on indigenous species for improvement of reservoir yields (e.g. silver barb) or in response to declining catches (e.g. *Pangassius sutchi*, *Pangasianodon gigas*, *Probarbus jullieni*, *Notopterus chitala* and *Osphronemus gouramy*) (Pawaputanon 1991, Virapat 1995). Indian carps and Chinese carps are stocked as well (Bernascek 1997). Stocking has not been very successful in the large reservoirs where the recovery rate has been estimated to be below 1% (Pawaputanon 1991). Virapat (1993) identified that one of the reasons for these relatively low return rates (in terms of biomass) was that stocked fish were recaptured far too early to utilize their growth potential. This illustrates that stocking must be evaluated with reference to the patterns of fishing. However, the Thais (both the government and village communities) carry out extensive and fairly successful stocking programs in small water bodies. They stock a mixture of carp species and Nile tilapia. Catches are dominated by the carps in water bodies of low to intermediate trophic status and by tilapias in the more fertile ones. Overall yield is strongly dependent on trophic status. It can be up to 2 880 kg/ha/year in fertile water bodies (Lorenzen *et al.* 1998a, Sugunan 1997).

In Japan *Oncorhynchus tschawytscha* was released in rivers for compensation stocking and *Ctenopharyngodon idella* was experimentally stocked for control of aquatic weeds. Ayu (*Plecoglossus altivelis*) has been stocked in Japanese rivers.

For many countries, the information in the Inland Fishery Enhancement Database was very limited, with only 1-4 entries (Figure 9). This, however, tends to underestimate the importance of stocking practices in certain countries. For example, many stock enhancement efforts have been carried out in Bangladesh with considerable success. The stocking of Indian major carps, silver carp, grass carp and common carp into oxbow lakes in the south-western part of the country (Oxbow Lakes Small Scale Fishermen Project, OLP I and II) considerably increased the yields (121 kg/ha in 1991-92 to 520 kg/ha in 1995-96) and the income of the target group of the project (Hasan & Middendorp 1998). Furthermore, in the Third Fisheries Project floodplains were stocked with Indian major carps, silver carp, common carp, kalibous (*Labeo calbasu*) and Thai sarputi (*Puntius gonionotus*) during the flood season in the period 1991-1996. The stocked biomass increased by 1.5 to 16 times and the overall results were economically viable (Ahmad *et al.* 1998, Ali & Islam 1998).

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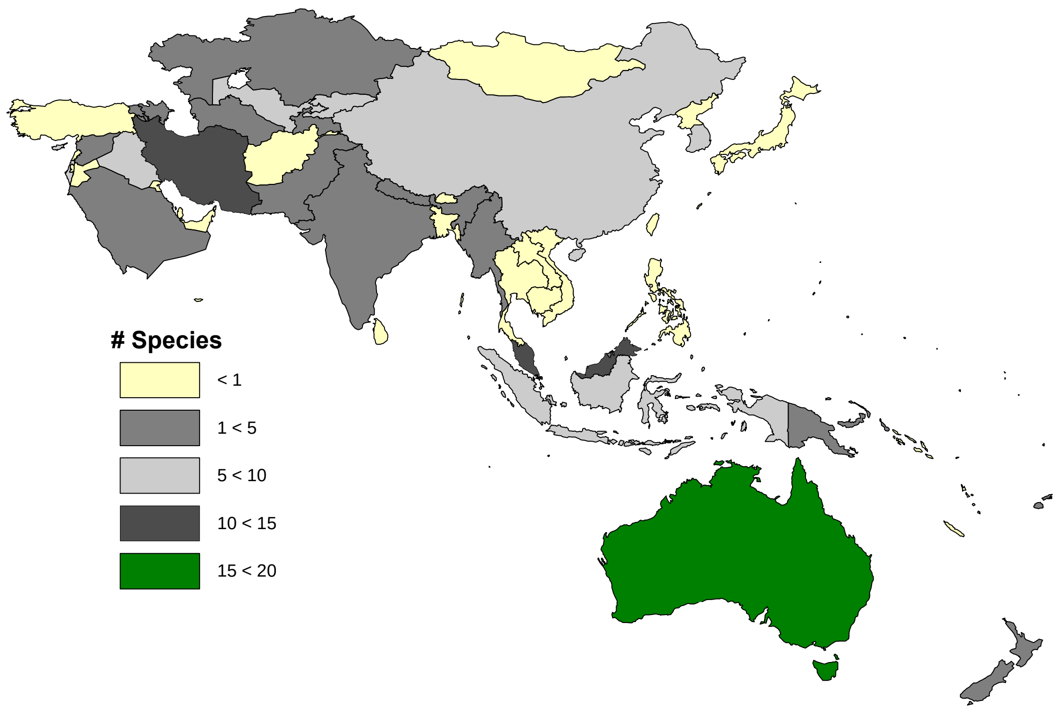
[5] See: http://www.fishnet.com.au/information/policy.html

In Figure 10 the number of species that are reported to FAO as produced in a hatchery and released into the wild are shown. Australia, Iran, Malaysia and The Republic of Korea report the highest numbers of species. For Australia, the same species as mentioned earlier are reported. In Iran, mahi sephid (*Rutilus frisii kutum*), Common carp and Chinese carps are the main species released into the wild. To a lesser extent sturgeons (*Acipenser* spp.) are also released. The Caspian Sea anadromous fishes Mahi sephid, sturgeon and Caspian trout (*Salmo trutta caspicus*) are stocked in response to declining catches due to water diversion and dam construction (Bartley & Rana 1998). In Malaysia, silver barb, bighead and common carp and Mozambique tilapia are the main species stocked in open waters. These have been released in reservoirs, river segments and tin mining pools, but the impacts of the stocking cannot be addressed properly due to lack of documentation and rational evaluation (Yap 1991). In The Republic of Korea common carp, chum salmon (*Oncorhynchus keta*), cherry salmon (*O. massou*) and rainbow trout (*O. mykiss*) are the main species released, but no further information is available on these stocking programs.

Figure 10: Number of freshwater species reported to FAO as being produced in hatcheries and released into open waters



Compared to the information in the Inland Fishery Enhancement Database, the hatchery production data give additional information on stocking practices that in certain cases does not appear in the former (e.g. Iran, The Republic of Korea).

In Table 12, an overview is given of the 15 most referred species in the Inland Fishery Enhancement Database and the most widely stocked species. Chinese carps, Indian carps and tilapias are the most important groups.

Table 12: Important stocked species in Asia and Oceania

Inland Fishery Enhancement Database		Hatchery Production Database	
Species name	# Entries	Species name	# Countries
Hypophthalmichthys molitrix	8	*Cyprinus carpio*	10
Aristichthys nobilis	7	*Hypophthalmichthys molitrix*	6
Indian Major Carps	6	*Oncorhynchus mykiss*	6
Labeo rohita	6	*Ctenopharyngodon idella*	5
Oreochromis mossambicus	5	*Lates calcarifer*	4
Oreochromis niloticus	3	*Oreochromis niloticus*	4
Oreochromis aureus	3	*Oreochromis mossambicus*	4
Salmo trutta	3	*Macrobrachium rosenbergii*	3
Plecoglossus altivelis	3	*Salmo trutta*	3
Ctenopharyngodon idella	3	*Mugil cephalus*	2
Catla catla	2	*Helostoma teminckii*	2
Chinese carps	2	*Aristichthys nobilis*	2
Cirrhinus mrigala	2	*Oncorhynchus tshawytscha*	2
Mugil cephalus	2	*Plectroplites ambiguus*	2
Tor putitora	2	*Puntius gonionotus*	2
		Labeo rohita	2
		Salmo salar	2
		Osphronermus gouramy	2

4.1.4 Other enhancements

Cage and pen culture in lakes and reservoirs can add substantial production to the resource. Information on cage culture was reported for China, Indonesia, Philippines and Nepal. Since the 1970s cage culture in China has developed at a rapid pace, with an annual expansion rate of 9.8% (Hu and Liu 1998). Rearing of fingerlings, mainly bighead, silver and grass carp, in coves that are blocked-off with nets or in cages is also widely practiced (Lu 1992, Li 1995). The fingerlings are either produced without feeding (filter feeders bighead and silver carps) or with additional feeding. The main species cultured for grow-out are common carp, grass carp, tilapia and mandarin fish (*Siniperca chautsi*). In Indonesia, cage culture was developed as a compensation measure for the displacement of 40 000 people that resulted from the construction of Saguling and Cirata dams in the heavily-populated highlands of West Java and resulted in a successful development of common carp culture (Costa Pierce 1992). The large-scale development of cage culture in these reservoirs has however also lead to a reduction in profit margins and deterioration of the water quality (Zianal and Effendi 1998). In Nepal, three lakes in Pokhara Valley are being used for cage culture of bighead and silver carp, which are raised in floating cages without supplemental feeding (Swar and Pradhan 1992).

Enhancement of natural resources is widely practiced in various countries in the region. Often these measures are taken in an attempt to restore an ecosystem. Habitat enhancement forms an integrated part of Chinese fishery enhancements. Protection of spawning grounds and installation of artificial nests are measures to increase the fish production, though these are generally less important compared to stocking (Li 1995). Furthermore, screening of the inflows and outflows to avoid predators from entering and stocked fish from escaping forms an essential part of the enhancement practices in Chinese reservoirs. A good example of environmental engineering can be found in Bangladesh where a channel that connects the floodplain with the main river channel was excavated to restore the natural recruitment to the floodplain. The percentile catch of migrating major carps and large catfishes increased from 2% to 24% after the intervention, indicating an improved immigration of these species. The total yield increased about 10 times, partly because of improved access to the fishery (Payne and Cowan 1998). This type of enhancement can also be classified as a restoration or rehabilitation measure, because the channel had been silted up, preventing the fish from entering the floodplain.

Several references mention the use of brush parks (FADs) to attract fish in coastal lagoons. In the Negombo lagoon in Sri Lanka, it was estimated that about 36% of the total catch were harvested with brush parks (Wijeyaratne & Costa 1987). Brush parks are also used in river fisheries in Bangladesh (Khata Fishery). Apart from the use as a fish attracting device for improved harvesting, the brush parks can also serve as sanctuaries to prevent over-fishing and poaching (very important during the dry season) and improving the habitat in general. For example, in Cambodia, fish sanctuaries have been rehabilitated with trees and trunks to prevent poaching, increase spawning habitat and improve the general fish habitat in the dry season (Thuok 1998).

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, 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).

4.1.5 Conclusions

A variety of practices exist in this region to enhance fishery production with introductions and stocking most commonly applied. Introductions to this region were mainly for the purpose of aquaculture but many of the species have established populations in open waters. Mozambique tilapia, common carp, rainbow trout and Chinese carps are the most important introduced species for commercial capture fisheries. Translocations of icefish within China and of several native species within Australia have also been important. Introductions have been generally more successful in the larger lakes and reservoirs (>1000 ha). 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) is important for recreational fisheries in Australia.

Practices of environmental engineering are not described frequently, but they do exist. Cage and pen culture is widespread in this region, notably in China, Indonesia and the Philippines. Other measures include screening of inlets and outlets, protection and construction of spawning habitats, re-establishment of floodplain-river connections, the construction of brush parks and re-establishment of migration pathways.

4.2 Africa

4.2.1 Inland fishery enhancements

Information on introductions is by far the most important in Africa, with stocking in second place (Figure 11). Few references relate to other enhancements.

In Africa, the majority of entries relate to fishery enhancements in natural lakes and reservoirs (Figure 12). Capture fisheries in Africa mainly occur on major lakes and man-made reservoirs, which is reflected in the figure.

Figure 11: Enhancement types entries for Africa

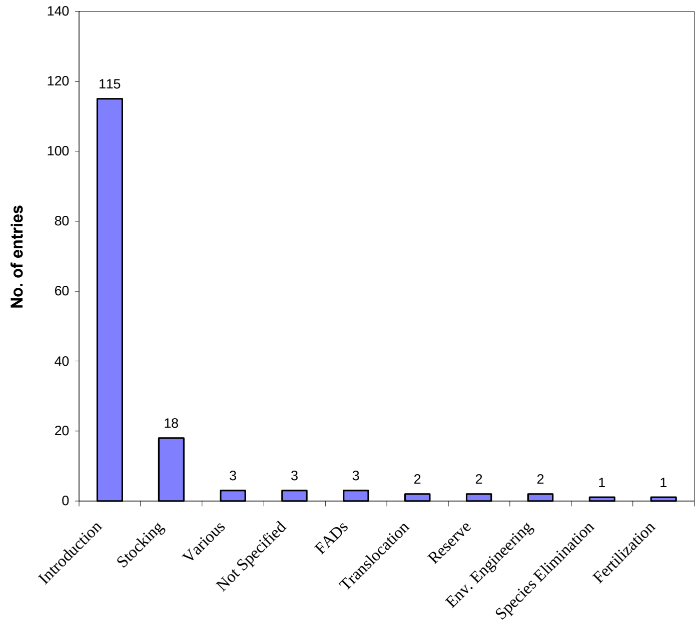
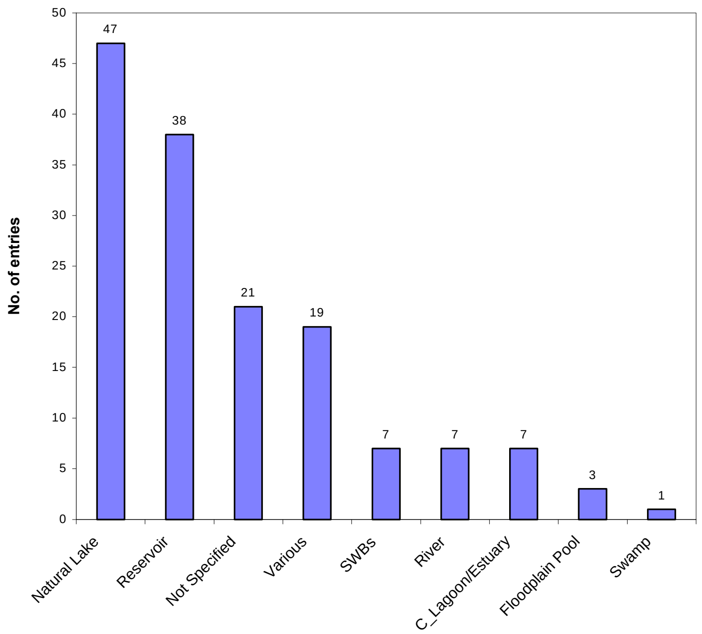


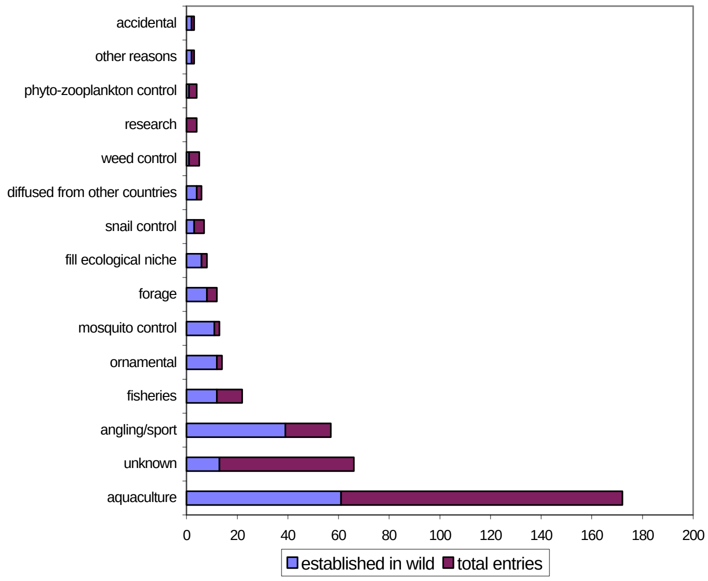
Figure 12: Water bodies distribution for fishery enhancements in Latin America



4.2.2 Introductions

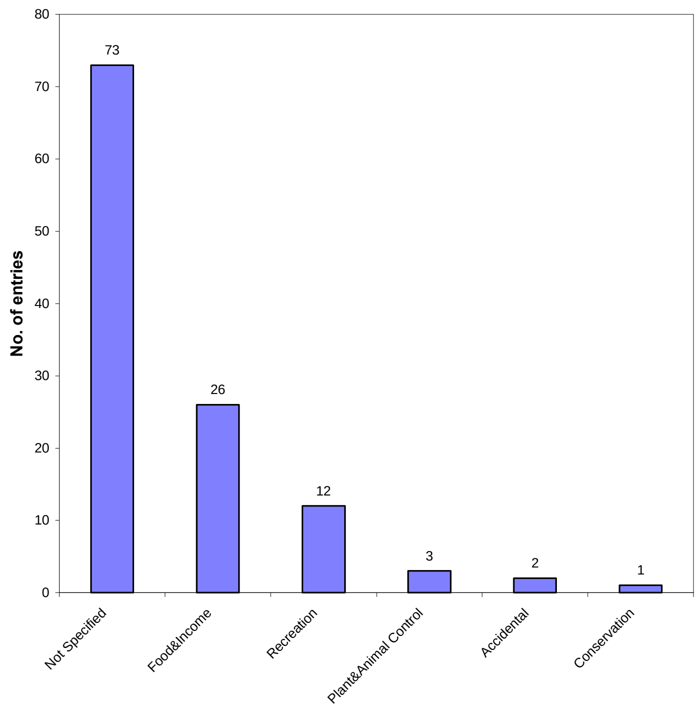
As for Asia, Oceania and Latin America, aquaculture is reported as the main reason for species introductions, followed by recreational fisheries and commercial fisheries (Figure 13). Most of the introductions are done for food production and income generation as can be seen in Figure 14. About 35% of the species introduced for aquaculture established self-sustaining populations but the percentage for recreational fisheries is higher (70%). Overall, 44% of the introduced species formed populations in open waters.

Figure 13: Reasons for introduction of freshwater species in Africa.



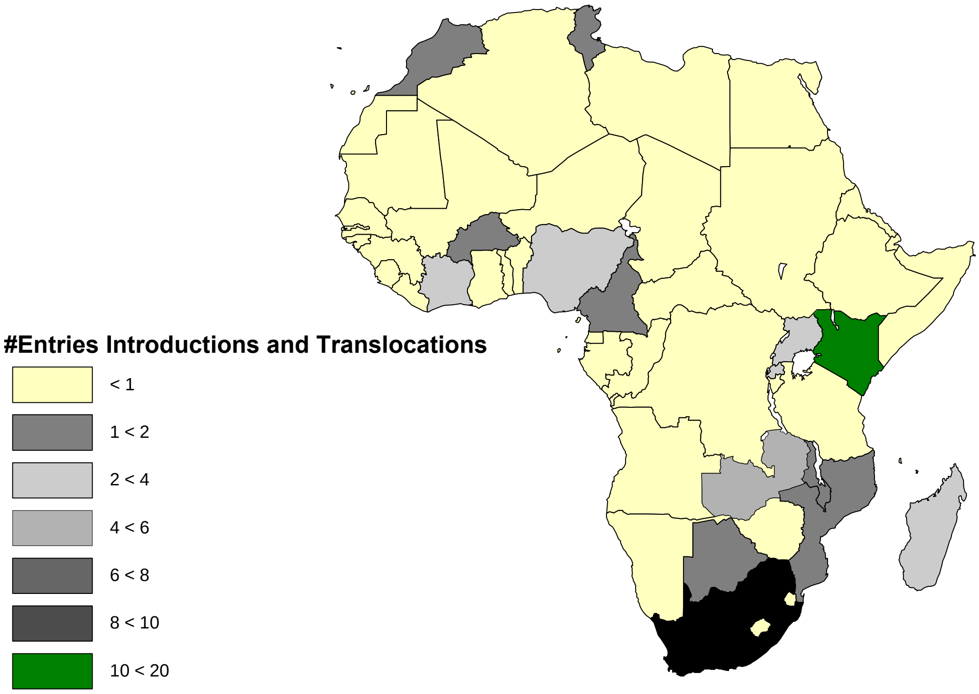
(*Source:* FAO Database on Introductions of Aquatic Species (DIAS))

Figure 14: Main purposes of introductions in Africa



As shown in Figure 15 and Figure 16 (on the following page), the majority of countries in Africa report introductions. Most information in ASFA is available for the countries bordering Lake Victoria (Kenya, Uganda, Tanzania), South Africa and Zambia (Figure 15). Reported introduced species are the highest for South Africa, Morocco, Madagascar, Zambia, Zimbabwe and Kenya (Figure 16).

Figure 15: Geographical distribution of information on introductions and translocations in Africa.



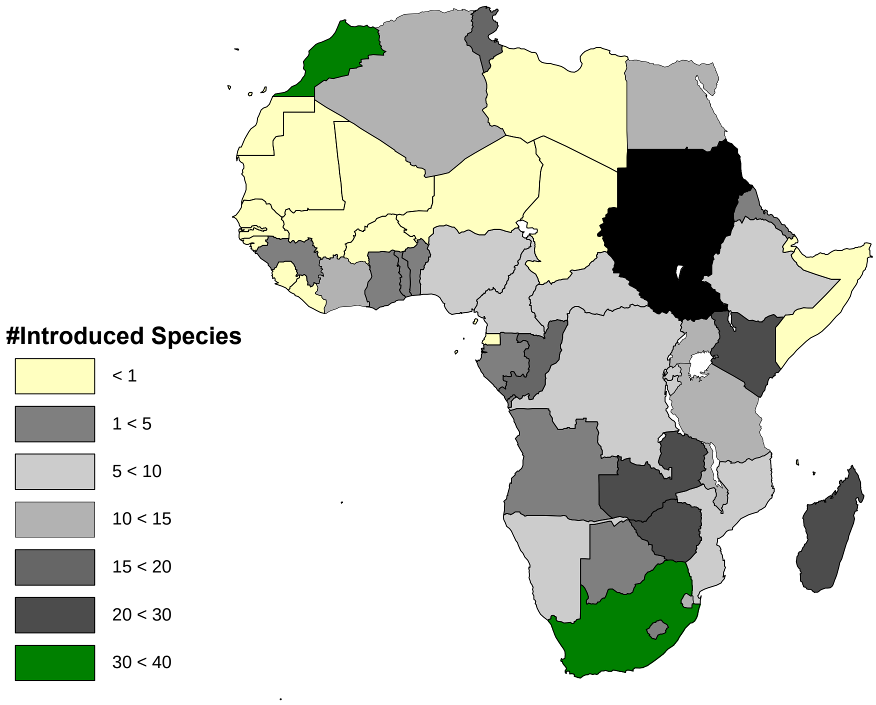
(Note: Entries for Lake Victoria were added to Kenya for mapping purposes)

Perhaps the most referred introduction worldwide is that of the Nile perch into Lake Victoria. A total of 18 references in the IFED deal with the introduction of *Lates niloticus* in Lake Victoria and its subsequent impact. Nile perch was released into Lake Victoria in 1954. Since then, a major commercial fishery has developed, with substantial economic and nutritional benefits (Reynolds and Greboval 1988). At the same time, it was reported that Nile perch is responsible for the reduction of the endemic haplochromid population (Goldsmith *et al.* 1993). However, environmental change and fishing pressure may have been equally, or even more important for the changes in Lake Victoria (Bundy and Pitcher 1995). An overview of the pros and cons of this introduction can be found in Pitcher and Hart (1995).

Another introduction, which received considerable attention, is that of the Tanganyika sardine (*Limnothrissa miodon*). The success of this species in Lake Tanganyika (where it is endemic) has led to its introduction into other lakes and reservoirs. In 1967, *L. miodon* was released into man-made Lake Kariba and this resulted in a sustainable fishery (Marshall 1991). Later on it colonized Cahora Bassa reservoir, downstream of Lake Kariba, through turbine passage (Lévêque 1998). No negative consequences have been reported to date in this reservoir (Lévêque 1998). This clupeid was also introduced into Lake Kivu, with considerable success and socio-economic and nutritional benefits (Spliethof *et al.* 1983).

Besides these two important introductions covering various countries (Uganda, Kenya, Tanzania, Zambia, Zaire, and Rwanda), many other species have been introduced in various countries as mentioned above. Of the 41 species introduced to South Africa, 21 established successfully, among them *Micropterus spp*. (released for sport fisheries), common carp, European perch, rainbow trout and silver carp. Sterile grass carp was introduced into the Florida Lake, Transvaal, and successfully reduced the weeds in the lake (Venter & Schoonbee 1991). Grass carps were also released in many dams in Natal Province (Pike 1990).

Figure 16: Distribution of species introductions in Africa



In the Limpopo River catchment, that drains considerable parts of Botswana, South Africa, Zimbabwe and Mozambique, 18 introduced species were recorded (Van der Mheen 1997). Silver carp has established a breeding population in the system, though they normally do not breed outside their natural range (Van der Mheen 1997).

A total of 35 species were introduced in Morocco of which 12 species established self-reproducing populations (Mouslih 1987), among them European perch, pikeperch (*Stizostedeon lucioperca*) and pike (*Esox lucius*), Lepomis spp., tench (*Tinca Tinca*), common carp, silver carp and crayfish (*Astacus astacus*).

Many species were introduced into Madagascar. Of the 23 species reported, 14 established in open waters. Important for open water fisheries and sport fisheries are giant gourami, large-mouth bass, common carp, salmon, rainbow trout, Heterotis and tilapias (*O. niloticus, O. macrochir, T. rendalli, T. zillii*) (Moreau 1987).

The main introduced species are presented in Table 13. Information on the introductions of Nile perch (*Lates niloticus*), Nile tilapia, Heterotis (*Heterotis niloticus*), rainbow trout and Lake Tanganyika Sardine (*Limnothrissa miodon*) is well presented in the Inland Fishery Enhancement Database. Except for Nile perch, introduced mainly to lake Victoria bordered by three countries, the above mentioned species colonized the inland waters of Africa successfully as can be seen in the table. Furthermore, common carp, mosquito fish (*Gambusia affinis*) and guppy (*Poecilia reticulata*) introduced to control insects and sunfish (*Lepomis macrochirus*) were established in many countries in the region.

Table 13: Important introduced species with reference to establishment in the wild for Africa

Most referred introduced species*			Established in wild**		
Genus	Species	# Entries	Genus	Species	# Countries
Lates	*niloticus*	18	*Micropterus*	*salmoides*	11
Oreochromis	*niloticus*	14	*Cyprinus*	*carpio*	10
Heterotis	*niloticus*	10	*Oreochromis*	*niloticus*	8
Oncorhynchus	*mykiss*	9	*Oncorhynchus*	*mykiss*	8
Limnothrissa	*miodon*	8	*Tilapia*	*rendalli*	8
Salmo	*trutta*	5	*Gambusia*	*affinis*	7
Cyprinus	*carpio*	4	*Oreochromis*	*mossambicus*	7
Micropterus	*salmoides*	3	*Lepomis*	*macrochirus*	6
Ctenopharyngodon	*idella*	2	*Heterotis*	*niloticus*	6
Barbus	*anoplus*	2	*Limnothrissa*	*miodon*	5
Oreochromis	*leucostictus*	2	*Poecilia*	*reticulata*	5
Tilapia	*zillii*	2	*Cyprinus*	*carpio*	4
Oreochromis	*spp.*	2	*Salmo*	*trutta*	4
			Tilapia	*zillii*	4
			Carassius	*auratus*	4

**Source:* Inland Fishery Enhancements Database
***Source:* FAO Database on Introductions of Aquatic Species

4.2.3 Stocking

Information about regular stocking practices in Africa is scarce, with 11 ASFA references for this region. The main reported purpose of the stocking programs is food production and income generation.

The distribution of the available information is presented in Figure 17 (see following page). Additional information about the number of species produced in hatcheries for release into open waters is given in Figure 18 (see following page). Morocco reports the highest number of freshwater species stocked notably, salmon (*S. trutta*), rainbow trout, and common carp, grass carp, pike and largemouth bass. The rest of the countries reporting stocking are spread over the continent, with seven countries reporting releases of one species of hatchery produced seed and nine countries 2-3 species (Figure 18).

The relatively high number of references for Ghana is based on proposed development of a culture based fishery with *O. niloticus*.

Zimbabwe has around 12 000 man-made reservoirs and many of these have been stocked with fish in the past. A special example is that of restocking of dams that dried up during the severe drought of 1991/92. Species were selected in order to increase production or because they were preferred by consumers or as sports fish (Van der Mheen 1994). This was however a one-time action and therefore not a repeated stocking program but rather a re-introduction. It is however referred to as stocking.

Figure 17: Geographical distribution of information on stocking in Africa

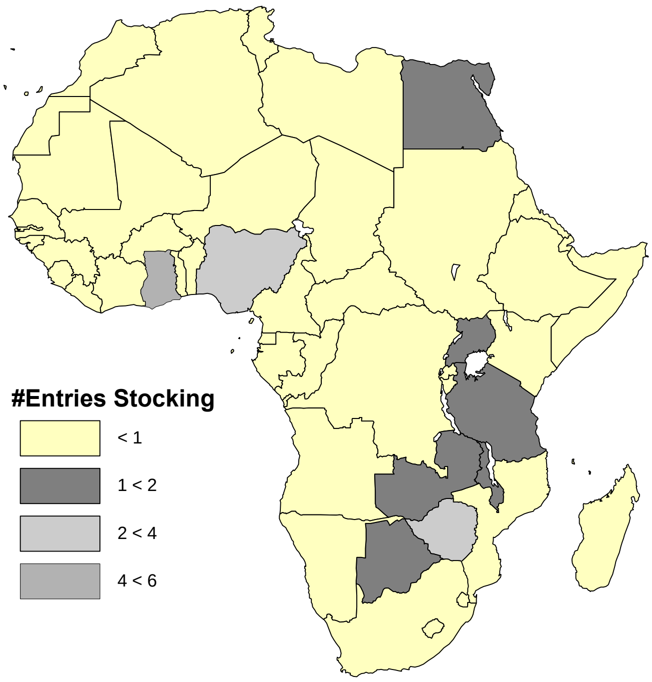
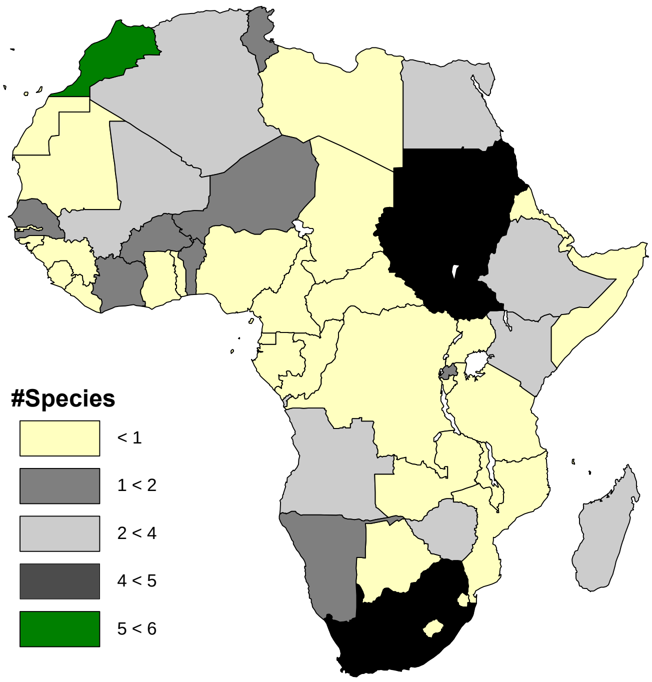


Figure 18: Number of freshwater species reported to FAO as being produced in hatcheries and released into open waters



In Nigeria, intensification of fish production from pools in an African floodplain, through water management, fertilization and stocking with fingerlings, was technically a success. Fish production per hectare was 171% greater in managed pools compared to unmanaged ones (Thomas 1994).

Lake Quarun, a closed inland lake in Egypt, is considered as the best site for growing and reproducing shrimps and has been stocked for five years with post larvae of *Penaeus kerathurus*, *Metapenaeus monoceros* and *Metapenaeus stebbingi* (Razek 1992). In Egypt stocking of Nile tilapia (*O. niloticus*) has been carried out on a regular basis by The Fishery Management Center at Aswan since 1988. Tilapia fry are artificially reproduced in a hatchery and reared in earthen ponds, close to the Aswan High Dam (Agaypi 1995). The effect of the stocking efforts is difficult to evaluate, because tilapia naturally reproduces in the Lake. In Burkina Faso, annual stocking of some small seasonal water bodies (< 50 ha maximum size) with *O. niloticus* and additional feed supply increased the yield considerably (Baijot *et al.* 1994). The main species used for regular stocking are listed in Table 14. Nile tilapia and rainbow trout are most widespread, followed by common carp.

Table 14: Important stocked species in Africa

Inland Fishery Enhancement Database		Hatchery Production Database	
Species name	# Entries	Species name	# Countries
Oreochromis spp.	2	*Oreochromis niloticus*	8
Penaeus spp.	1	*Oncorhynchus mykiss*	6
		Cyprinus carpio	4
		Salmo trutta	3
		Micropterus salmoides	3
		Oreochromis mossambicus	2
		Ctenopharyngodon idella	2

4.2.4 Other enhancements

As can be seen in Figure 11, information on other enhancement types than stocking and introductions is very limited. The information on FADs refers to evaluation of the Acadja or brush park fishery in coastal lagoons in Côte d’Ivoire. The ecological changes that result from the installation of these brushparks induce a strong eutrophication of the benthic ecosystem and sustainable fish production therefore calls for strategic spatio-temporal planning to take account of the progressive eutrophication in these lagoons (Guiral *et al.* 1995). No information is provided about the effects on fisheries production. In the Niger Delta region the possibility of hydraulic engineering was investigated to manipulate freshwater and seawater inputs so as to increase aquatic and wetland productivity, but no results or actual activities were described (Nalaguo 1985). The principles and options for hydraulic engineering of lagoons to enhance fisheries production were reviewed by Miller *et al.* (1990) and basically include management of freshwater input, modifications of water exchange with the sea and modification of internal circulation. Manipulation of exchange with the sea has been practiced in the Tunis Lagoon and probably has had positive impacts (Miller *et al.* 1990). Additionally, a 30% increased yield has been reported through improvement of fish migration and regulation of fishing effort in this lagoon (Chauvet 1984).

4.2.5 Conclusions

Introductions have been significantly more important than stocking in this continent. Apart from the introductions of Nile perch and Lake Tanganyika sardine that have resulted in the establishment of significant fisheries, tilapias, common carp and rainbow trout have been distributed over this continent. Largemouth bass and sunfish have been introduced for recreational fisheries in eleven and six African countries respectively. Many species were introduced into Madagascar and contribute considerably to fisheries and sport fisheries.

On the other hand, information on stocking practices 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 bigger 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 describe the brush park fishery in lagoons in Côte d'Ivoire and hydraulic management in lagoons, but the information is very scarce.

4.3 Latin America

4.3.1 Inland fishery enhancements

Introductions and stocking are mostly referred to in the database for Latin America, with hardly any information on environmental engineering and fertilization (Figure 19). The total number of references is relatively low, compared to Asia and Oceania.

The majority of water bodies used for fishery enhancement in Latin America are reservoirs and lakes (Figure 20), followed by rivers and one reference for an oxbow lake in Brazil.

Figure 19: Enhancement types for Latin America

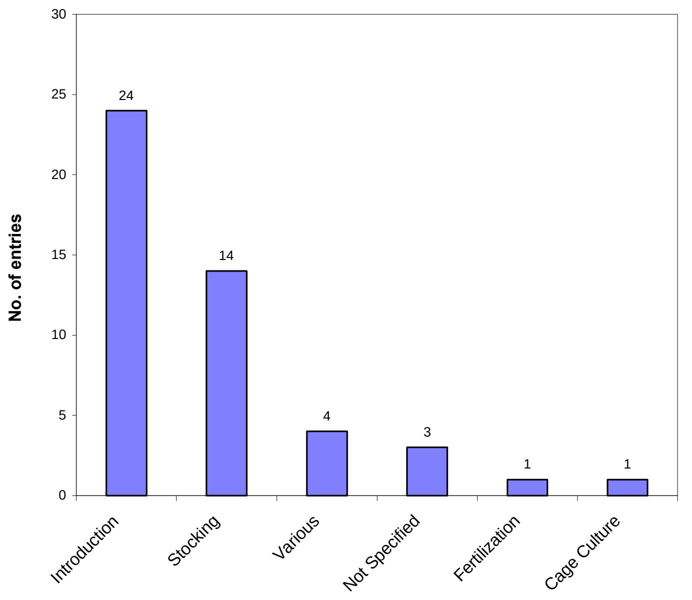


Figure 20: Water bodies distribution for fishery enhancements in Latin America

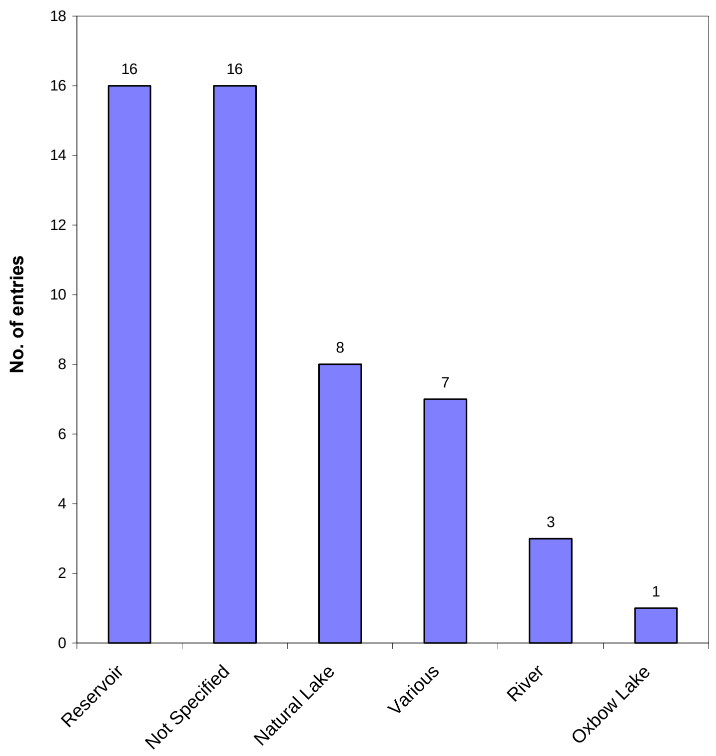
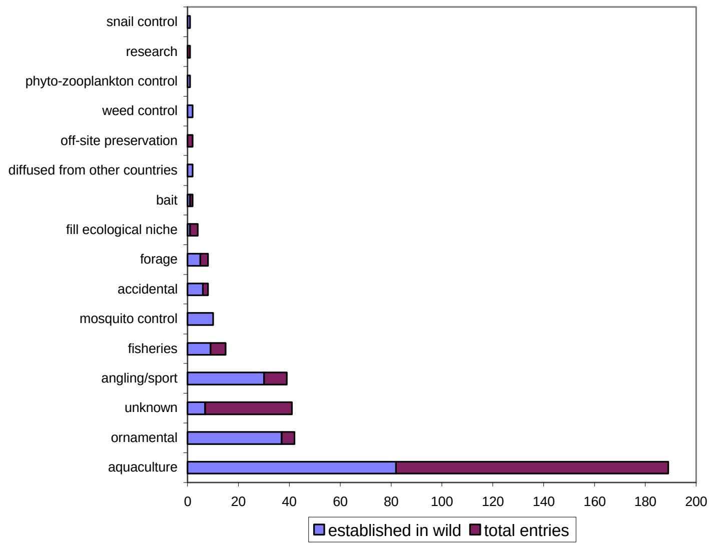


Figure 21: Reasons for introduction of freshwater species in Latin America.

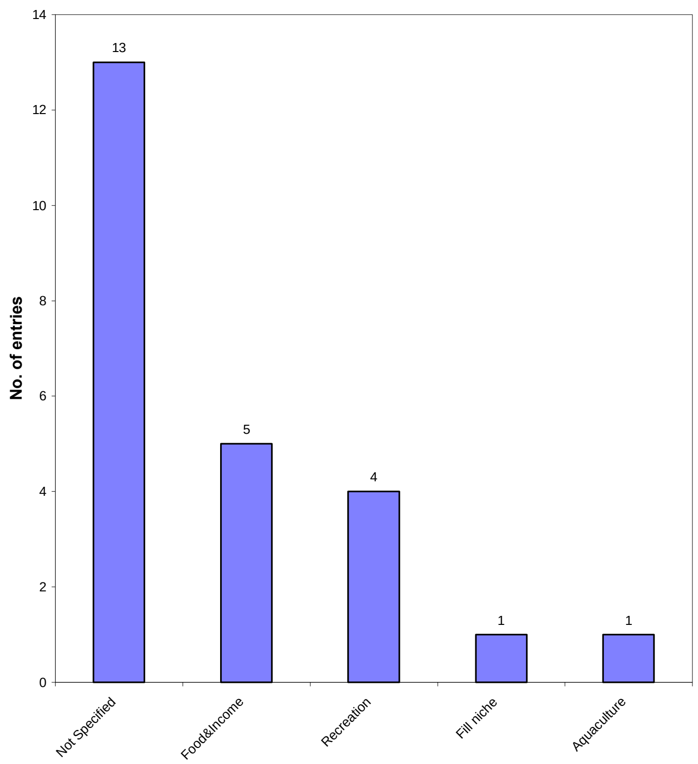


(*Source:* FAO Database on Introductions of Aquatic Species (DIAS))

4.3.2 Introductions

The main reason for introduction of aquatic species in Latin America is for the purpose of aquaculture, followed by ornamental fish production, recreational fisheries and fisheries improvement (Figure 21). The majority of ornamental and sport fishes have become established in open waters, whereas for aquaculture this is the case for nearly half (43%) of the introductions. Most of the references dealing with introductions relate to food production, income generation and recreational fisheries, but the number of references is very low (Figure 22).

Figure 22: Main purposes of introductions in Latin America



The geographical distribution of information on introductions and the number of introduced species per country are shown in Figure 23 and Figure 24, respectively. The countries with the highest number of introduced species and the most information available are Colombia, Brazil, Mexico and Chile.

Figure 23: Geographical distribution of information on introductions in Latin America

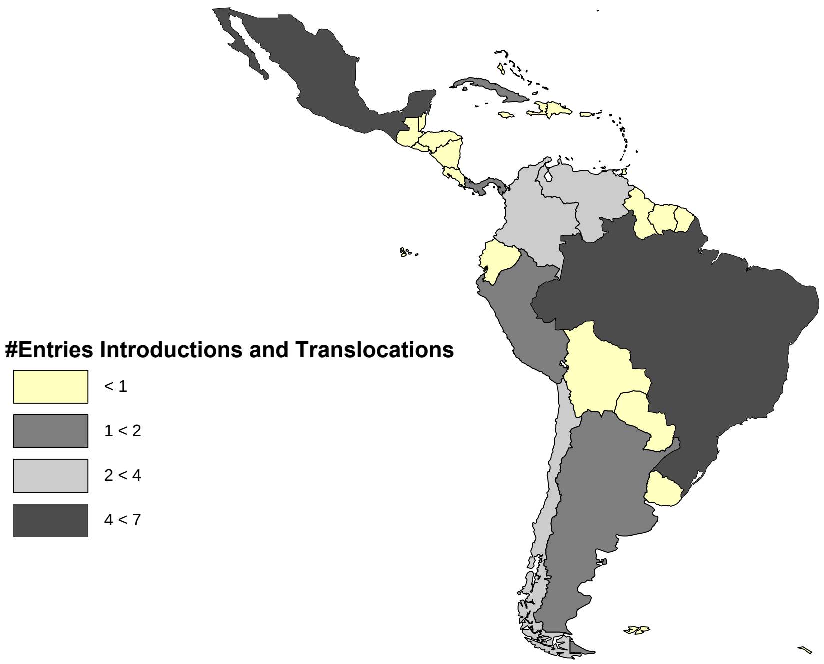
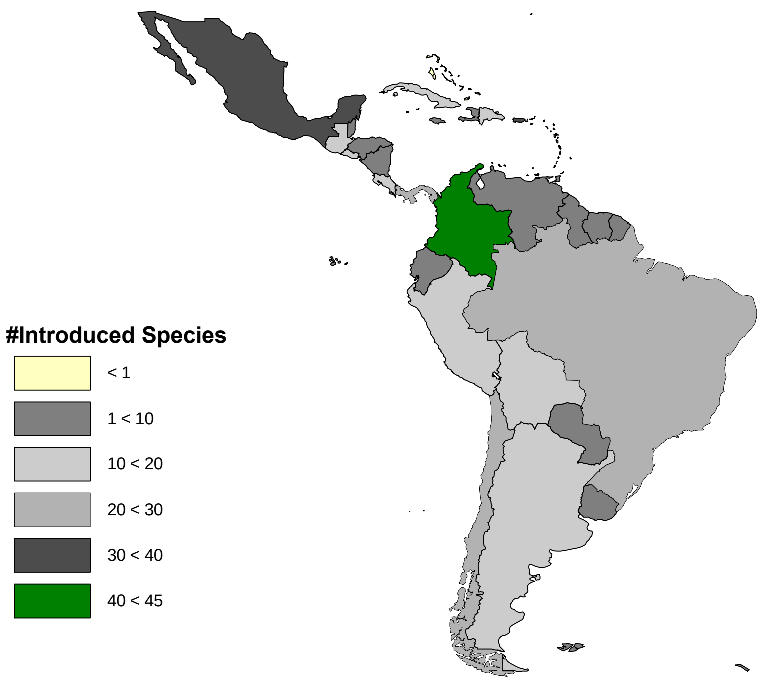


Figure 24: Distribution of species introductions in Latin America



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

Of the 42 species introduced to Colombia, 31 have become established in the wild. *O. mossambicus* was introduced in 1953, followed by *Tilapia rendalli* in 1962 and *O. niloticus* in 1979 which all formed self-reproducing populations in lakes and reservoirs and contribute significantly to the total fish production in the country (Castillo Campo 1996). Further information about the other introduced species and their role in the inland capture fisheries in Colombia is, however, not available from the literature found in the present study.

In Brazil, eight of the 21 introduced species have established themselves in open waters. These are tilapias (*T. rendalli*, *O. niloticus*, *O. aureus*. *O. urolepus honorum*, common carp, *Carassius auratus*, green sunfish (*Lepomis cyanellus*) and Siamese fighting fish (*Betta splendens*). The introduction of 42 fish species into the reservoirs of Northeast Brazil resulted in the establishment of 14 species. Notably *T. rendalli* and *O. niloticus* form an important component of the fish catch in these reservoirs (Gurgel and Fernando 1994). The average annual yield of these species increased from 45 kg/ha before introduction to 120 kg/ha at present. Common carp and tambaqui (*Colossoma macropomum*) were, however, not successfully established (Gurgel and Fernando 1994). Information on introductions and the effects on the fishery production in the rest of Brazil is scarce.

In Mexico, 23 of the 39 introduced species have become established in the wild. In the Lama river basin, a main river system in the country, eleven exotic species have been reported as established, among them tilapias (*O. mossambicus* and *O. aureus*), common carp and rainbow trout (Lyons *et al.* 1998). Species have also been transplanted, such as blue catfish (*Ictalurus fructatus*), black bass (*M. salmoides*), and *Chrisostoma* spp. and became established (Arrendodo-Figuerora 1983). Introduced and transplanted species contribute significantly to the overall fish production in Mexico, but also have had significant impacts on the native fish fauna.

Of the 23 species introduced to Chile, twelve have become established. These include salmonids, *Salvelinus fontinalis* and cameleon cichlid (*Cichlasoma facetum*) which are cold waters species. Pacific salmon has been introduced within the framework of a Japan-Chile cooperation program initiated in 1996 (Anonymous 1990).

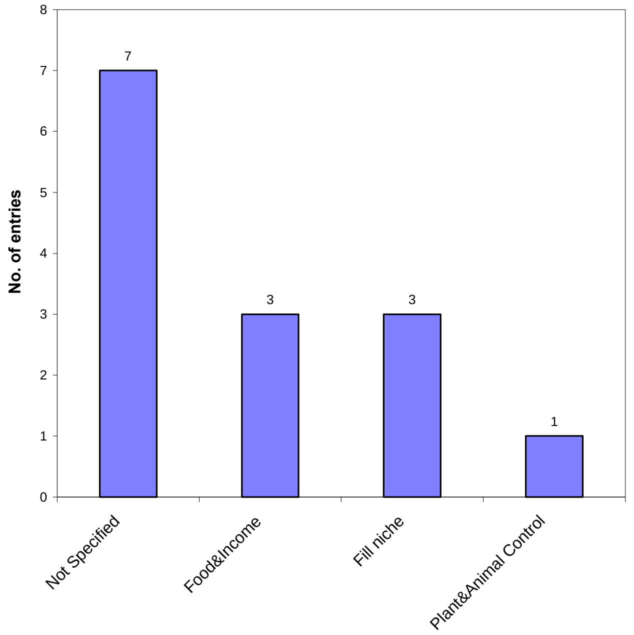
Tilapias have been widely introduced in this region (Table 15). Since 1950, seven tilapia species have been introduced to Latin America and in many cases these species contribute significantly to the fishery production (Juarez-Palacios and Olmos-Tomassini 1991). Common carp is also relatively wide spread.

Table 15: Important introduced species with reference to establishment in the wild for Latin America

Most referred introduced species*			Established in wild**		
Genus	Species	# Entries	Genus	Species	# Countries
Tilapia	*rendalli*	2	*Oreochromis*	*mossambicus*	14
Oreochromis	*niloticus*	2	*Oreochromis*	*niloticus*	12
Oncorhynchus	*spp.*	2	*Cyprinus*	*carpio*	10
Tilapia	*spp.*	1	*Oreochromis*	*aureus*	9
Salmo	*trutta*	1	*Micropterus*	*salmoides*	8
Oreochromis	*spp.*	1	*Oreochromis*	*urolepis hornorum*	7
Oncorhynchus	*mykiss*	1	*Oncorhynchus*	*mykiss*	7
Oncorhynchus	*keta*	1	*Salmo*	*trutta*	6
Micropterus	*salmoides*	1	*Gambusia*	*affinis*	6
Ctenopharyngodon	*idella*	1	*Carassius*	*auratus*	6
Cichla	*temensis*	1	*Salvelinus*	*fontinalis*	5
Cichla	*ocellaris*	1	*Tilapia*	*rendalli*	5
			Procambarus	*clarkii*	4
			Poecilia	*reticulata*	4
			Odontesthes	*bonariensis*	3
			Lepomis	*macrochirus*	3

* *Source:* Inland Fishery Enhancements Database
** *Source:* FAO Database on Introductions of Aquatic Species

Figure 25: Main purposes of stocking in Latin America



4.3.3 Stocking

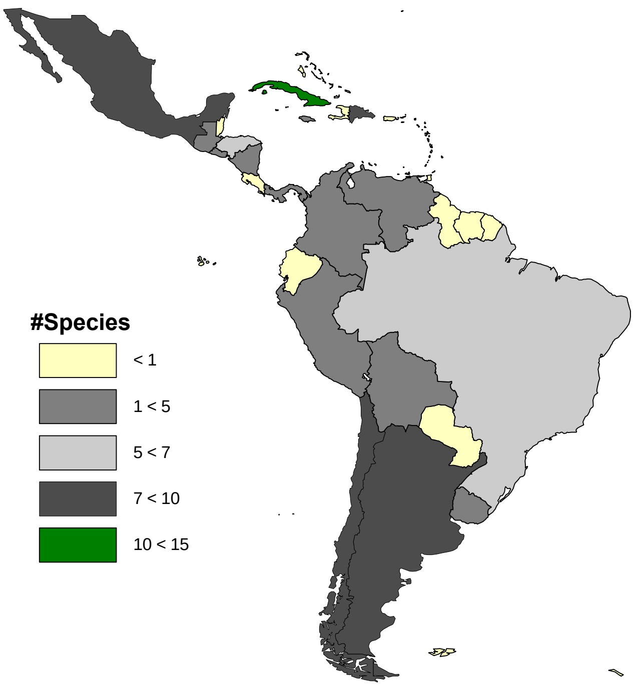
As for introductions in Latin America, the information on stocking practices is also very limited. Food production, filling a vacant niche and plant and animal control are the purposes for stocking in this region (Figure 25).

The information from Brazil and Argentina is relatively abundant (Figure 26 on the following page). The number of species stocked in Cuba, Argentina, Chile and Mexico are the highest (Figure 27 on the following page).

Cuban inland fisheries thrive mainly on the stocking of tilapia (*O. aureus*) and Chinese carps (silver, bighead and grass carp) in reservoirs. In 1994, 180 million tilapia seed and 79 million carp seeds were produced in Cuban hatcheries (Sugunan 1997). Tilapia is partly stocked to compensate for reduced natural spawning due to water level reduction (Juarez-Palacios and Olmos-Tomassini 1991), but mainly to increase production. It is however questionable if supplemental stocking of tilapia does have a significant effect on the yield if adequate natural reproduction exists (Quirós and Mari 1999). Carps are generally doing better when stocked in the smaller reservoirs, partly because they are more difficult to harvest completely in the larger water bodies (Sugunan 1997).

Figure 26: Geographical distribution of database entries on stocking in Latin America

Figure 27: Number of freshwater species reported to FAO as being produced in hatcheries and released into open waters



The main species produced in hatcheries and reported as released into Argentinean inland waters are three salmonid species, brook trout (*Salvelinus fontinalis*), *Basilichthys bonariensis argentinensis* and Creol perch (*Percichthys trucha*). Mastrarrigo (1981) reports that silver-sides and European perch have also been stocked. There seems to be considerable potential for extensive culture of rainbow trout in reservoirs in the temperate regions of the country (Patagonia, Andes, Pampa) but to date these resources are not exploited, partly because of lack of interest to develop them (Chiodo, pers.comm.). The Centro de Ecologiá Aplicada de Nuequén (CEAN) produced about 3 million rainbow trout and Atlantic salmon (*S. salar sebago*) fry, principally for aquaculture, but part of this production is released into river segments to enhance recreational fisheries.

Reported stocking in Chile mainly relates to the release of anadromous salmonids into inland waters to enhance sea migrating stocks.

In Brazil, stocking efforts are concentrated in the Northeast region of the country (Juarez-Palacios and Olmos-Tomassini 1991, Barbosa and Hartmann 1998, Sugunan 1997). Since 1909, the National Department for Works against Droughts (DNOCS) has developed initiatives to increase the fisheries yields in the reservoirs in this region, which were constructed in response to re-occurring severe droughts. Stocking has been the main tool. Because DNOCS has faced serious budget cuts since 1980, a German-Brazilian joined project was initiated in 1991 to develop reservoir fisheries in 5 reservoirs in this region. The species that have been stocked are tilapia and tucunaré (*Cichla monoculus*). Tilapia yields have increased considerably as a result (Barbosa and Hartmann 1998), though the contribution of natural reproduction is not clear. Despite stocking of tambaqui (*Colossoma macropomum*), significant quantities of this species did not appear in the catch (Barbosa and Hartmann 1998).

Reference to regular stocking of tilapia is made for Mexico, Guatemala, Honduras, Nicaragua, Panama and Peru (Juarez-Palacios and Olmos-Tomassini 1991), but no hatchery production for release into the wild was reported to FAO for these countries. In Mexico a new federal Secretariat for Environment, Natural Resources and Fisheries (SEMARNAP) was formed in 1995, which has created a network of fish seed centers (39) for stocking of reservoirs. The main species for release into reservoirs are tilapias (58%) and carps (25%), Common and Chinese carps (Sugunan 1997). Black bass is also reproduced and stocked.

Table 16 gives an overview of the most important species that are stocked in the region. Rainbow trout, *O. niloticus* and common carp are the most widely distributed.

Table 16: Important stocked species in Latin America

Inland Fishery Enhancement Database		Hatchery Production Database	
Species name	# Entries	Species name	# Countries
Oreochromis spp.	3	Oncorhynchus mykiss	7
Plasgioscion squamosissimu	1	Oreochromis niloticus	4
Perca fluviatis	1	Cyprinus carpio	4
Oncorhynchus spp.	1	Colossoma macropomum	3
Oncorhynchus mykiss	1	Basilichthys bonariensis	2
Hypophthalmichthys molitrix	1	Hypophthalmicht hys molitrix	2
Cyprinus carpio	1	Oreochromis aureus	2
Colossoma macropomum	1		
Cherax tenuimanus	1		

4.3.4 Other enhancements

As shown in Figure 19, two references refer to other enhancements, namely fertilization and cage culture. The reference regarding fertilization describes the natural increase of nutrients in an oxbow lake due to water level fluctuations (Camargo and Esteves 1995). It is therefore not artificial fertilization, but the findings of such a study could be used with respect to water management.

In Argentina, cage culture is practiced in Alicurá reservoir, Neuquén Province with a total production of 1.190 metric tons per year. The species are rainbow trout and Atlantic salmon. In Chile salmon is also grown in cages. Furthermore there have been some experimental and small scale activities regarding tilapia culture in cages. No information was found about environmental engineering as an enhancement tool in this region.

4.3.5 Conclusions

Species have been introduced all over Latin America and tilapias and salmonids have created significant fisheries in this region. Common carp is also widely distributed, but some unsuccessful introductions have also been reported. Stocking is practiced in various countries, notably in Cuba (tilapia and Chinese carps in reservoirs), Argentina and Chile (salmonids), Brazil (tilapias in Northeast Brazilian reservoirs) and recently Mexico (tilapias, common and Chinese carps in reservoirs). Cage culture is practiced in reservoirs in Argentina 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.

Figure 28: Distribution of enhancement types in North America

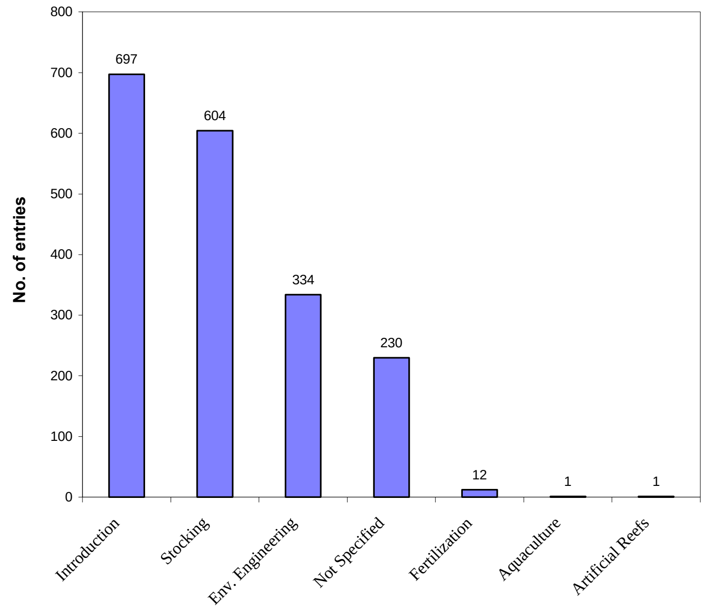
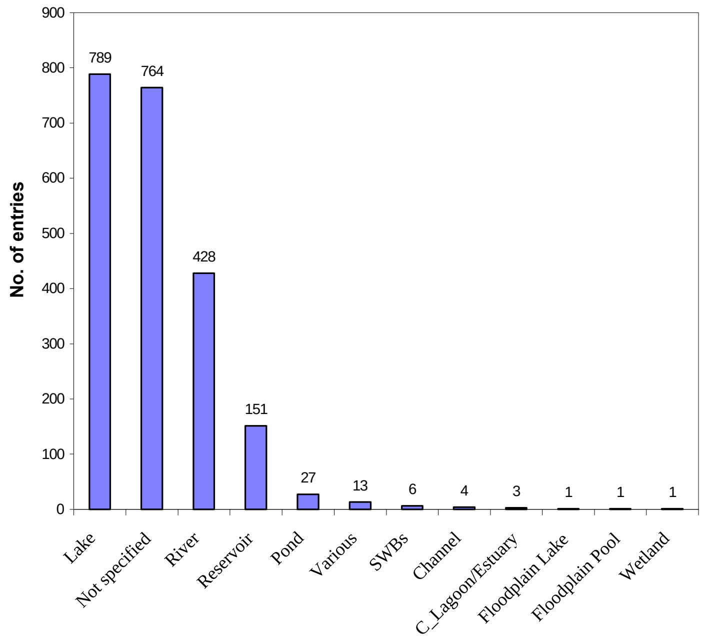


Figure 29: Water bodies distribution for fishery enhancements in North America



4.4 North America

4.4.1 Inland fishery enhancements

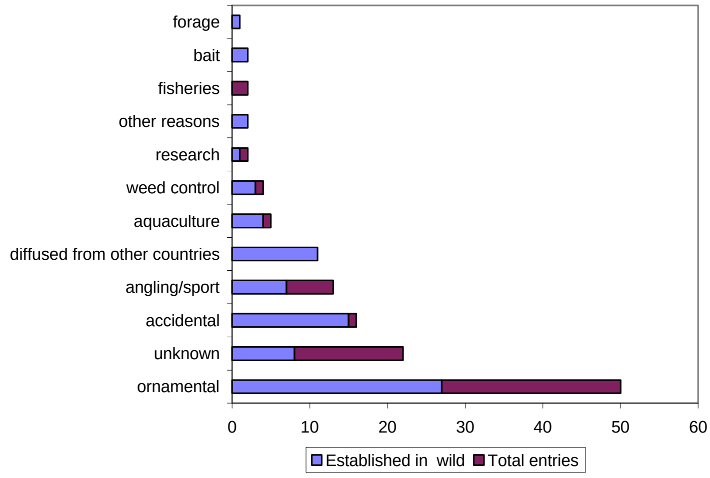
A total of 1864 references were downloaded for the USA and Canada of which 604 references were characterized as stocking, 697 as introductions and 321 as environmental engineering (Figure 28). The references to environmental engineering have not been included for this analysis.

Most of the introductions and stocking practices are targeted at lakes, followed by rivers and reservoirs (Figure 29). Flood-plains/wet-lands, ponds and other small water bodies and channels are also represented. The total area of small water bodies (< 16 ha) in the USA was about 4 million hectares in 1982 and about half was located in the south-eastern states (Moehl and Davies 1993).

4.4.2 Introductions

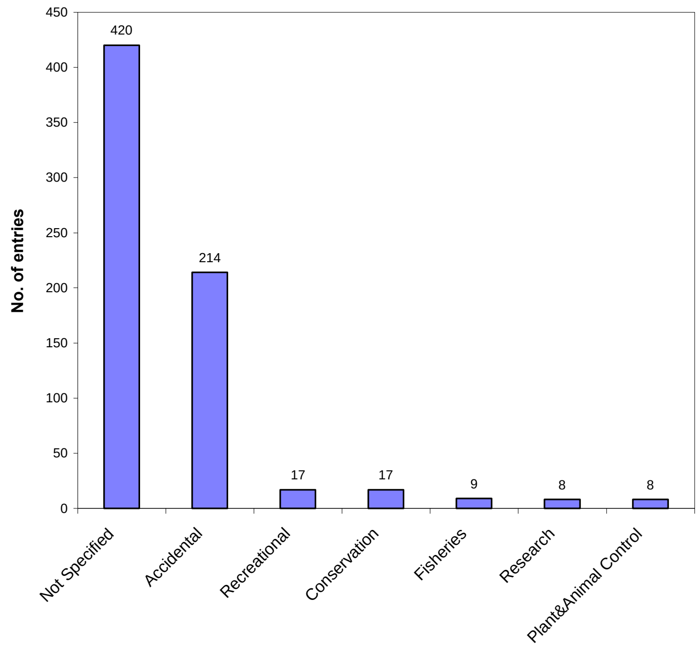
The main reasons for introductions as derived from the introductions database are given in Figure 30. Introductions of ornamental fishes are listed as most important, followed by accidental introductions (including those through ballast water), recreational fisheries and diffused from other countries. Compared to the other continents, few species have been introduced for aquaculture purposes. The purposes derived from the ASFA search are presented in Figure 31 and show that accidental introductions are important, especially the invasion of the zebra mussel (*Dreissena polymorpha*) and its impact on the native aquatic fauna (214 references) as well as that of the invasion of the sea lamprey (*Petromyzon marinus*) that is held responsible for the decline of the lake trout (*Salvelinus namaycush*) in the Great lakes (Lake Ontario, Michigan, Huron and Superior). The colonization of Lake Superior (Ogle *et al.* 1996), and other Great Lakes with ruffe (*Gymnocephalus cernuus*) has also received considerable attention.

Figure 30: Reasons for introduction of freshwater species in North America.



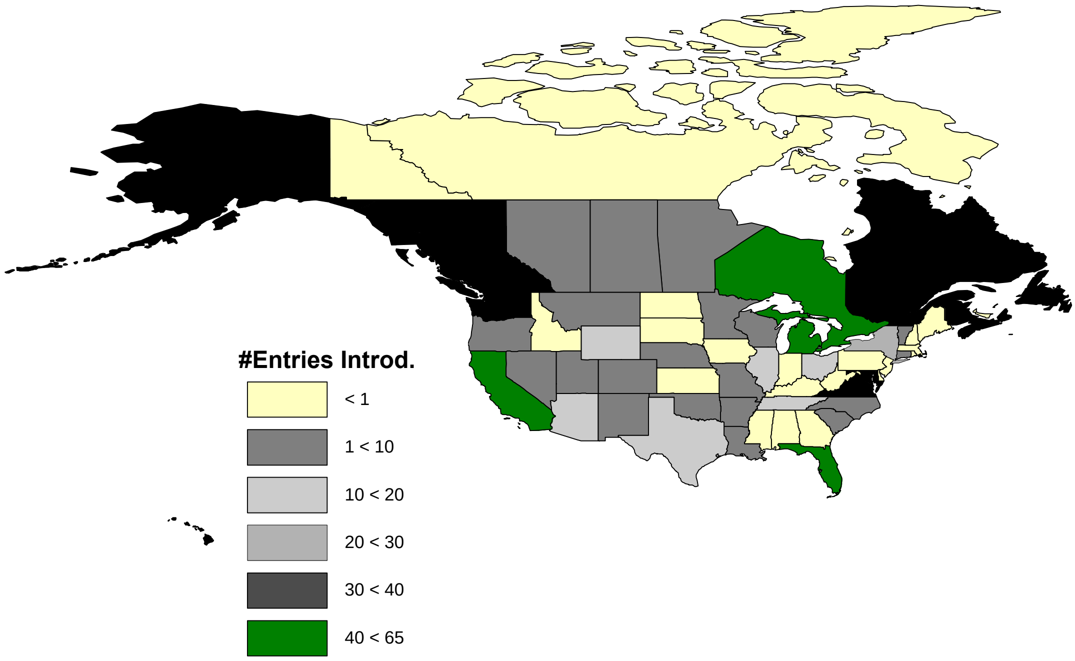
(*Source:* FAO Database on Introductions of Aquatic Species (DIAS))

Figure 31: Main purposes for introductions in North America



The geographical distribution of the information on introductions is presented in Figure 32. The states with relatively high numbers of references in the ASFA search are California, Florida, Michigan, New York and Ontario.

Figure 32: Geographical distribution of information on introductions and translocations in North America



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 saxatilis*) contributed for 42-77% to the angling catch in this State (Lee 1995). Furthermore, shad (*Alosa sapidissima*) and striped bass were introduced to the Sacramento-San Joaquin river system (Stevens, *et al.* 1987). Other introductions and translocations into California include that of coho salmon (Bartley *et al.* 1992), *Tilapia zillii*, *O. mossambicus* and *O. honorum* for control of aquatic weeds (Legner 1983) and mosquito fish.

Butterfly peacock bass (*Cichla ocellaris*) was introduced into 11 coastal canals in Florida, where it has established self-reproducing populations and it contributes significantly to the sports fisheries in the area, without significant negative impacts (Shafland 1995). 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).

In Ontario, Michigan and New York states, introductions of Atlantic salmon (*S. salar*) into Lake Ontario was done to restore the population (Jones *et al.* 1993). Pacific salmon (*Oncorhyngus* spp.) was introduced in the tributary streams of Lake Ontario (Rand *et al.* 1992) and the introduction of white perch *(Morone americana*) was successful. Since then 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).

Table 17 gives an overview of the reported introduced species with commercial importance in North America. *S. fontinalis* was successfully transplanted in four lakes in Ontario, Canada, (Fraser 1989) but it has not been translocated extensively in North America. However, lake trout (*S. namaycush*) has been widely introduced 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).

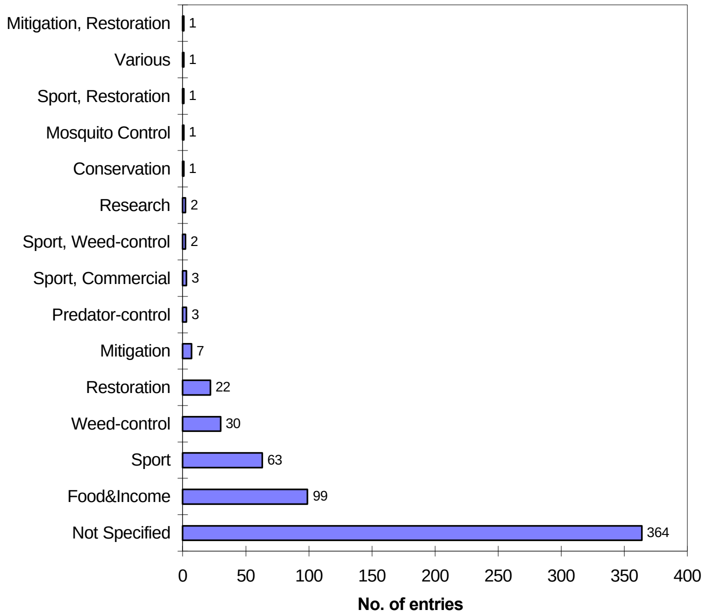
Table 17: Important introduced species with commercial significance with reference to establishment in the wild for North America

Most referred introduced species*			Established in wild**		
Genus	Species	GameFish	Genus	Species	GameFish
Salvelinus	*fontinalis*	Yes	*Neogobius*	*melanostomus*	No
Ctenopharyngodon	*idella*	Yes	*Oncorhynchus*	*gorbuscha*	Yes
Micropterus	*salmoides*	Yes	*Tinca*	*tinca*	Yes
Morone	*saxatilis*	Yes	*Misgurnus*	*anguillicaudatus*	No
Oncorhynchus	*mykiss*	Yes	*Alosa*	*sapidissima*	Yes
Salmo	*salar*	Yes	*Ameiurus*	*melas*	Yes
Salvelinus	*namaycush*	Yes	*Anguilla*	*japonica*	No
Oncorhynchus	*gorbuscha*	Yes	*Astronotus*	*ocellatus*	Yes
Stizostedion	*vitreum*	Yes	*Cichla*	*temensis*	Yes
Alosa	*pseudoharengus*	No	*Cichlasoma*	*urophthalmus*	Yes
Petromyzon	*marinus*	No	*Clarias*	*batrachus*	No
Morone	*americana*	Yes	*Acanthogobius*	*flavimanus*	No
Neogobius	*melanostomus*	No	*Hypomesus*	*nipponensis*	No
Oncorhynchus	*nerka*	Yes	*Oreochromis*	*aureus*	No
Perca	*flavescens*	Yes	*Oreochromis*	*mossambicus*	Yes
Esox	*lucius*	Yes	*Perca*	*flavescens*	Yes
Gymnocephalus	*cernuus*	Yes	*Platichthys*	*flesus*	Yes
			Pomoxis	*nigromaculatus*	Yes
			Rivulus	*hartii*	No
			Salmo	*trutta trutta*	Yes
			Tilapia	*zillii*	No
			Cyprinus	*carpio*	Yes

* *Source:* Inland Fishery Enhancements Database
** *Source:* FAO Database on Introductions of Aquatic Species

Rainbow trout has been introduced into Appalachian streams where it dominates native brook trout (Clark and Rose 1997) and this species is also reported to exhibit introgression with native steelhead trout (Williams *et al.* 1996) and hybridization with Apache trout *(O. apache)* (Carmichael *et al.* 1993).

Figure 33: Main purposes of stocking in North America



4.4.3 Stocking

Figure 33 provides an overview of the purposes of stocking. Main reasons identified are for fisheries purposes (food and income), recreational fisheries, weed control and restoration. An example of a restoration effort is the case where four large hydroelectric dams block spawning migrations of anadromous American shad *Alosa sapidissima* in the Susquehanna River. Transplantation to upstream areas and supplementary stocking with hatchery reared larvae resulted in a successful restoration of the population (Hendricks 1995). The stocking of lake trout in response to sea lamprey predation in the Great Lakes is another example of restoration stocking. Grass carp is the main species stocked for weed control. The stocking of small impoundments for recreational fisheries is a widely applied practice in the USA. Moehl and Davies (1993) list a total of 34 species stocked for this purpose. The stocking of largemouth bass (*Micropterus salmoides*) together with its prey species bluegill (*Lepomis macrochirus*) is often used (Moehl and Davies 1993).

The geographic distribution of stocking information is presented in Figure 34 (on the following page). The highest number of references is found for the states bordering the Great Lakes, Florida and on the West Coast: Oregon, Washington and British Columbia.

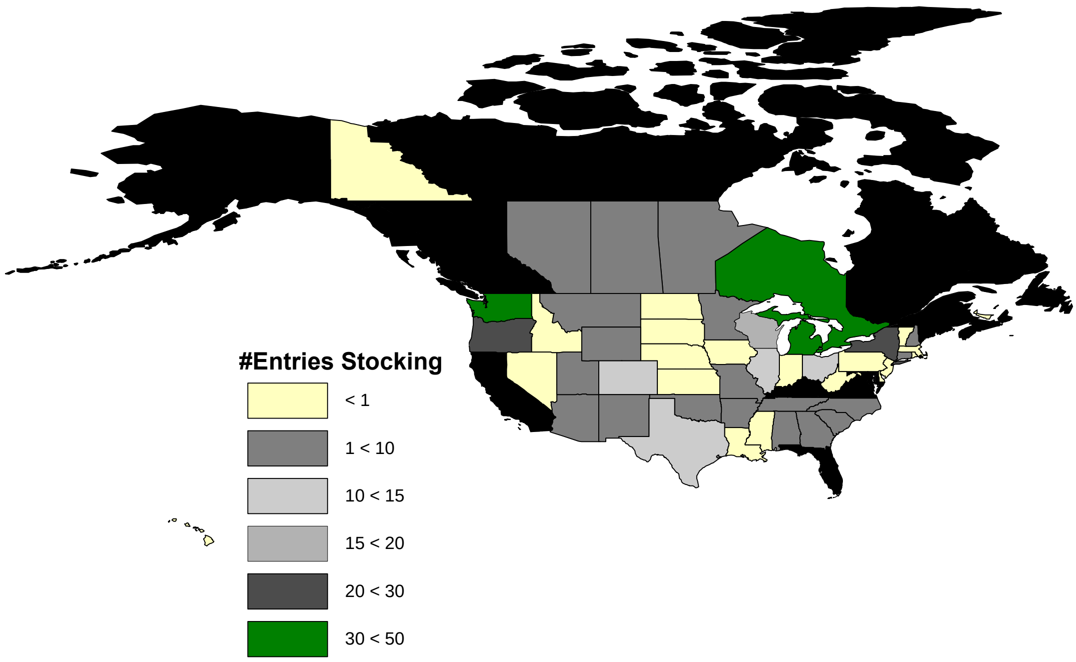
Table 18: Summed stocking effort in the Great Lakes* in the period 1950-1987.

Species name	Genus	Species	No. Stocked
Lake trout	*Salvelinus*	*namaycush*	157758125
Chinook salmon	*Oncorhynchus*	*tshawytscha*	124725255
Coho salmon	*Oncorhynchus*	*kisutch*	89900808
Rainbow	*Oncorhynchus*	*mykiss*	25228067
Steelhead	*Oncorhynchus*	*mykiss*	25021285
Brown trout	*Salmo*	*trutta fario*	24501062
Brook trout	*Salvelinus*	*fontinalis*	3691652
Palomino			102316

* The five Great Lakes; Erie, Huron, Michigan, Ontario, Superior plus lake St. Clair.
Source: Great Lakes Fish Stocking Database (http://www.glfc.org/dbfs.htm).

The stocking efforts in the Great Lakes area are listed in Table 18. A total of 8 species have been stocked since 1950, notably lake trout and Chinook salmon. Stocking of lake trout, together with sea lamprey control and catch restrictions were used to enhance remnant lake trout stocks in Lake Superior and re-establish lake trout in Lakes Michigan, Ontario, Erie, and Huron. The loss of genetic diversity among wild lake trout stocks in the Great Lakes imposes a severe constraint on lake trout rehabilitation (Burnham-Curtis *et al.* 1995). Walleye (*Stizostedion vitreum vitreum*) has been stocked since 1970 at Saginaw Bay, Huron Lake, in response to a collapsed fishery/fisheries in the late 1940s due to poor reproduction and other factors. By 1988, a sport fishery had developed which yielded 134 000 walleyes, one-sixth or less of the bay's biological potential (Mrozinski *et al.* 1991). In Lake Michigan walleye populations were restored through stocking (Schneider *et al.* 1991). Walleye stocks were also enhanced through regular stocking in lake Winnipegosis, Canada, using an automatic lift-gate technique (Scott 1982). In Lake Michigan, stocking of rainbow trout, lake trout, brook trout, brown trout, coho salmon, and Chinook salmon has created a significant sports fishery with a tenfold increase of angler effort between 1963 and 1985 (Hansen *et al.* 1990).

Figure 34: Geographical distribution of database entries on stocking in North America



Information on stocking efforts in Florida mainly relates to the release of grass carp for weed control. In the West Coast States, various efforts have been undertaken to restore and enhance salmonid stocks, notably Chinook salmon in Snake River, Washington (Burgert *et al.* 1995), Yakima River (Fast *et al.* 1991) and other rivers and streams. Experimental stocking of channel catfish (*Ictalurus punctatus*) fingerlings into six Washington lakes gave good results in terms of growth and survival (Bonard *et al.* 1997).

In British Columbia 10.1 million fish were released into over 1 000 lakes and streams in 1993. This release included 5.4 million rainbow trout and 1.1 million steelhead, which are the main species used to enhance and manage recreational fisheries in small lakes (Hume and Tsumura 1992, Ludwig 1995). Stocking of various salmonids is widely practiced in British Columbia.

Table 19 gives the important species that are stocked in North America.

Table 19: Main species stocked in North America

Inland Fishery Enhancement Database	Hatchery Production Database
Species Name	Species Name
Salvelinus namaycush	*Oncorhynchus gorbuscha*
Stizostedion vitreum	*Oncorhynchus keta*
Oncorhynchus mykiss	*Oncorhynchus tshawytscha*
Salmo salar	*Oncorhynchus mykiss*
Salvelinus fontinalis	*Oncorhynchus nerka*
Ctenopharyngodon idella	*Stizostedion vitreum*
Oncorhynchus tshawytscha	*Oncorhynchus kisutch*
Micropterus salmoides	*Esox lucius*
Oncorhynchus nerka	*Oncorhynchus spp.*
Oncorhynchus kisutch	*Salvelinus namaycush*
Morone saxatilis	*Morone saxatilis*
Ictalurus punctatus	*Lepomis macrochirus*
Alosa pseudoharengus	*Ictalurus punctatus*
Oncorhynchus gorbuscha	*Salmo salar*
Perca flavescens	*Micropterus salmoides*

4.4.4 Conclusions

A vast number of references related to introductions were found for this region (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 involves those of various species to enhance recreational fisheries in small impoundments, notably black bass, catfish (*Ictalurus* spp.), sunfishes (*Lepomis* spp.) and striped bass (*Morone saxatilis).* Atlantic, pink and Pacific salmon were introduced to several Great Lakes. Blue tilapia, accidentally introduced to Florida waters became established and created a significant fishery there. Brook trout was successfully transplanted to Lake Ontario, but is not so widespread. Lake trout has been introduced in some of the Great Lakes where it was not indigenous.

Stocking of largemouth bass, its prey species bluegill and other sport fishes is widely practiced 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.

4.5 Europe

4.5.1 Inland fishery enhancements

References on stocking (400 references) and introductions (280 references) were specifically searched for in ASFA and hence appear in the database as shown in Figure 35. Stocking and introductions are mainly performed in lakes and rivers, followed by reservoirs (Figure 36).

Figure 35: Distribution of enhancement types in Europe

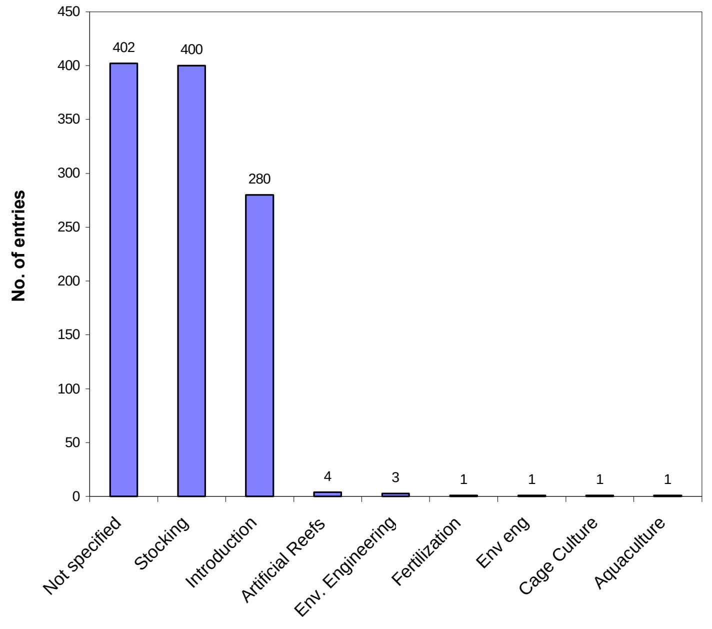


Figure 36: Water bodies distribution for fishery enhancements in Europe

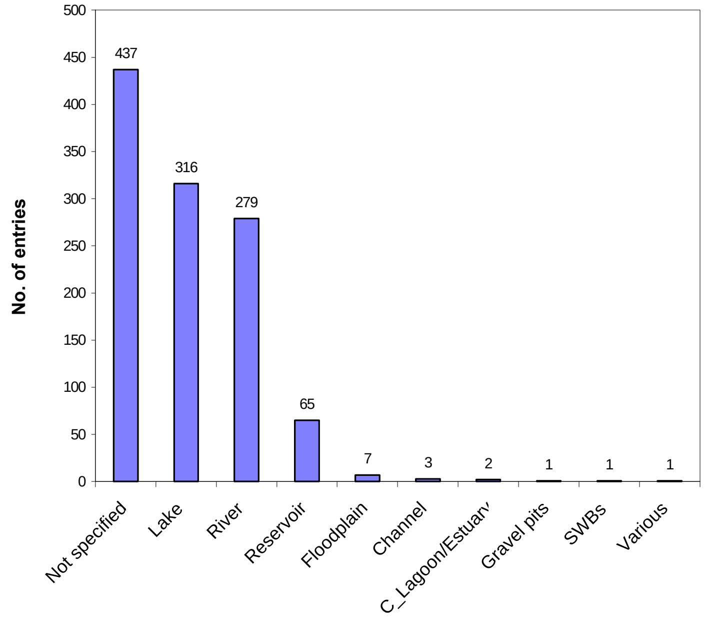
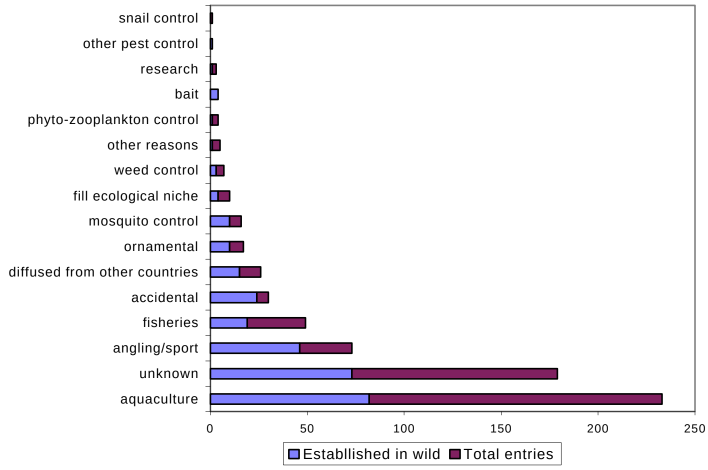


Figure 37: Reasons for introduction of freshwater species in Europe



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

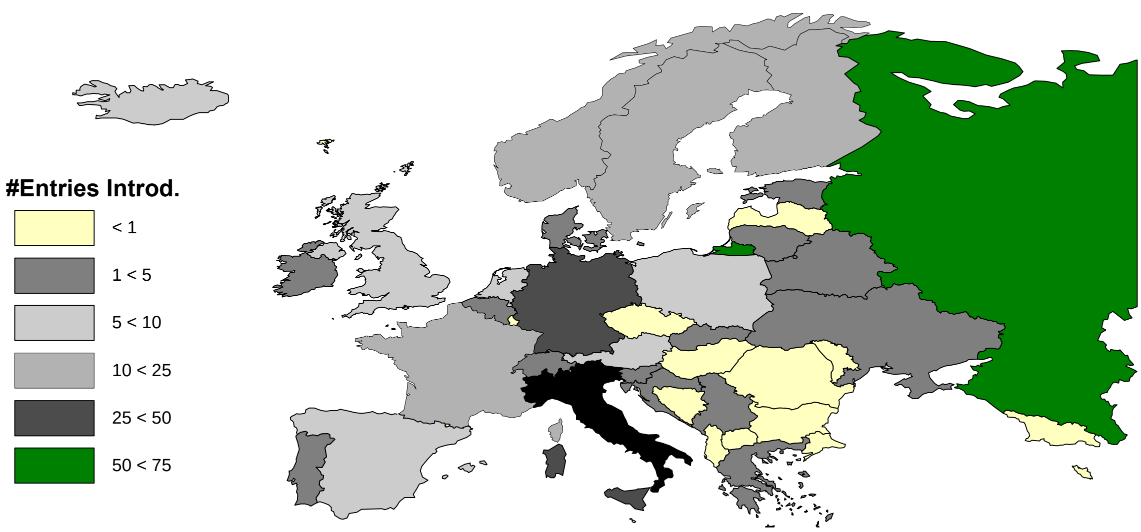
4.5.2 Introductions

The main reasons for introductions in Europe are presented in Figure 37. Aquaculture is the most important one, followed by recreational fisheries and commercial fisheries. The geographical distribution of the information is presented in Figure 38 and the number of introduced species per country is given in Figure 39 (shown on the following page).

A relatively large amount of information is available about introductions in the Former USSR, the Scandinavian countries (Norway, Sweden and Finland), Germany, Italy and France.

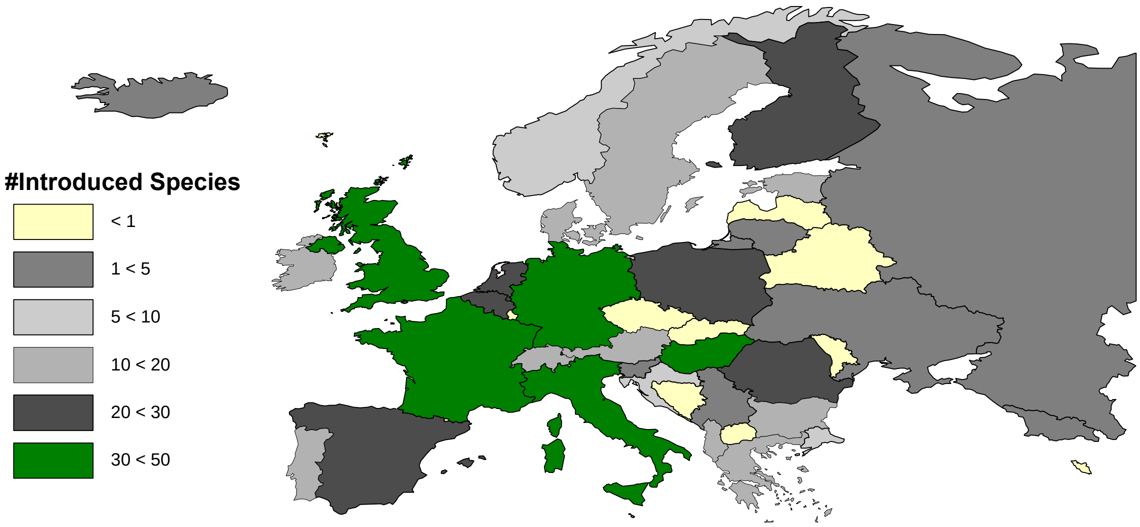
A total of 72 species have been introduced to the Former USSR of which 29 have become established. Chinese carps (grass, silver and bighead), bream (*Abramis brama*), common carp, pikeperch (*Stizostedion lucioperca*), wels catfish (*Silurus glanis*) and peled (*Coregonus peled*) have successfully adapted in Soviet lakes and reservoirs (Berka 1990). Introductions have played an important part in Balkhash lake where most introduced species successfully established except for grass carp which suffered heavy predation (Berka 1990). 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 of 13 percent less than the native Azov stocks (Tsvetnenko 1993). Pikeperch was successfully introduced into Lake Vozhe (Bolotova *et al.* 1995) and rainbow

Figure 38: Geographical distribution of information on introductions and translocations in Europe



trout has been introduced in Irkutsk Reservoir (Angara River) 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 to Lake Baikal, were it has been recorded already (Shirobokov 1993).

Figure 39: Distribution of species introductions in Europe



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

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). Crayfish (*Pacifastacus leniusculus*) were introduced in Lake Iso-Majajaervi and Lake Karisjaervi, Finland but the development of the population has been slow and catches and population sizes have been quite low (Westman and Savolainen 1995, Kirjavainen and Westman 1995). This crayfish also invaded the fresh waters of Sweden and is considered responsible for the decline in native noble crayfish (*Astcus astacus*) through competition and disease transfer (Soederbaeck 1995). 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).

Information on introductions in Germany mainly relates to introduced crayfish, ruffe and grass carp for recreational fisheries. Seventeen species have been established in open waters in Germany, among them rainbow trout, carp (*Cyprinus carpio*), *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 acclimatize 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, colonizing 136 lakes (Machino 1996).

An overview of introduced species in Europe is given in Table 20.

Table 20: Important introduced species with commercial significance with reference to establishment in the wild for Europe

Most referred introduced species*			Established in wild**		
Genus	Species	GameFish	Genus	Species	GameFish
Salvelinus	*alpinus*	No	*Cyprinus*	*carpio*	Yes
Rutilus	*rutilus*	No	*Ameiurus*	*melas*	Yes
Hypophthalmichthys	*molitrix*	No	*Oncorhynchus*	*mykiss*	Yes
Ctenopharyngodon	*idella*	Yes	*Stizostedion*	*lucioperca*	Yes
Aristichthys	*nobilis*	No	*Coregonus*	*peled*	No
Stizostedion	*lucioperca*	Yes	*Hypophthalmichthys*	*molitrix*	No
Oncorhynchus	*gorbuscha*	No	*Silurus*	*glanis*	Yes
Abramis	*brama orientalis*	Yes	*Salvelinus*	*namaycush*	Yes
Coregonus	*peled*	Yes	*Tinca*	*tinca*	Yes
Oncorhynchus	*mykiss*	No	*Esox*	*lucius*	Yes
Salvelinus	*fontinalis*	Yes	*Anguilla*	*anguilla*	Yes
Ictalurus	*punctatus*	Yes	*Carassius*	*carassius*	Yes
Perccottus	*glenii*	No	*Aspius*	*aspius*	Yes
			Coregonus	*lavaretus*	Yes
			Coregonus	*nasus*	Yes
			Abramis	*brama*	Yes
			Ictalurus	*punctatus*	Yes
			Ictiobus	*bubalus*	Yes
			Liza	*aurata*	No
			Mugil	*cephalus*	Yes
			Neogobius	*melanostomus*	No
			Oncorhynchus	*kisutch*	Yes
			Perca	*fluviatilis*	Yes
			Rutilus	*rutilus*	Yes
			Salmo	*salar*	Yes
			Hemibarbus	*maculatus*	No

* *Source:* Inland Fishery Enhancements Database
** *Source:* FAO Database on Introductions of Aquatic Species

4.5.3 Stocking

Information on stocking is relatively abundant in Finland, France, Germany, Poland and Italy (Figure 40 on the following page). The highest numbers of different species stocked are found in Poland, Finland and France (Figure 41 on the following page). Stocking is commonly used in lake fisheries management in Finland. There exist some 15 000 lakes, exceeding 10 ha in size in this country. Brown trout (*Salmo trutta fario*) has been stocked extensively and the majority of yields rely on regular stocking of this species (Vehanen and Aspi 1996). The most important species stocked are whitefish, vendace (*Coregonus albula*), pikeperch, Atlantic salmon (*S. salar*) and brown trout. European eel (*Anguilla anguilla*) is stocked in productive lakes in southernmost Sweden, Lake Vombsjoen and Lake Ringsjoen where it constitutes approximately 5% of the total trawl catch biomass (Hamrin 1990). Eel is also stocked and introduced to maintain populations in small lakes in southern Finland (Pursiainen and Tulonen 1986).

The main species stocked in France are brown trout, rainbow trout, pike, common carp, tench (*Tinca tinca*) and eel. Alpine lakes are furthermore stocked with lake trout and brook trout, for example in lake stocking of *Salvelinus alpinus* in the Annecy Lake, Haute Savoie (Baud 1994) and anadromous salmonids are stocked for restoration, for example in the Nivelle River, Southwest France (Dumas and Clement 1994).

Many stocking efforts are also reported in Poland. A reported 22 species are produced in hatcheries and released into the wild. Many experimental stocking studies are reported, mainly related to anadromous salmonids. Main species released are *Coregonus albula*, pike, *C. lavaretus*, *Salmo trutta trutta* and *Salmo trutta fario*. White fish (*Coregonus* sp.) is widely stocked into lakes and reservoirs in Germany.

Figure 40: Geographical distribution of database entries on stocking in Europe

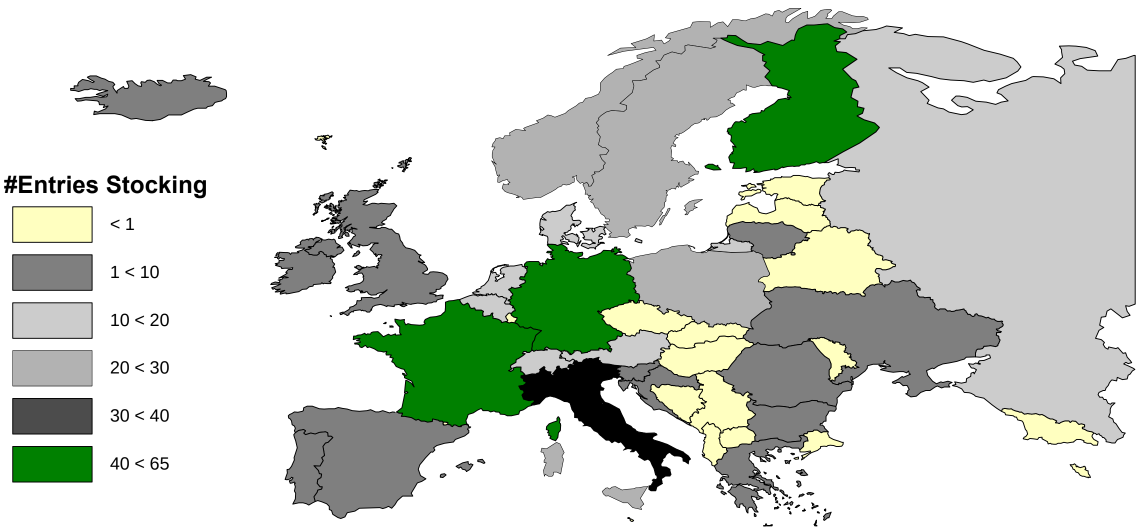
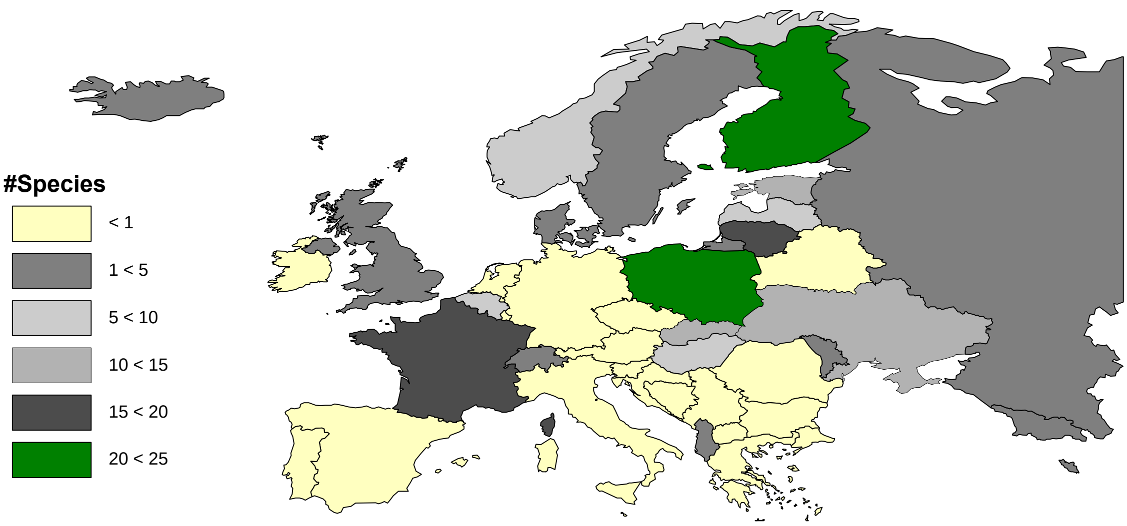


Figure 41: Number of freshwater species reported to FAO as being produced in hatcheries and released into open waters



The most important species that are stocked in Europe are presented in Table 21.

Table 21: Main species stocked in Europe

Inland Fishery Enhancement Database	Hatchery Production Database
Species Name	Species Name
Salmo salar	*Coregonus spp.*
Salvelinus alpinus	*Cyprinus carpio*
Esox lucius	*Acipenseridae*
Stizostedion lucioperca	*Salmo trutta*
Perca fluviatilis	*Oncorhynchus mykiss*
Coregonus albula	*Cyprinus carpio,Carassius carassius*
Thymallus thymallus	*Coregonus albula*
Rutilus rutilus	*Esox lucius*
Ctenopharyngodon idella	*Salmo salar*
Oncorhynchus mykiss	*Tinca tinca*
Salvelinus fontinalis	*Coregonus lavaretus*
Coregonus peled	*Varicorhinus capoeta sevan*
Tinca tinca	*Stizostedion lucioperca*
Hypophthalmichthys molitrix	*Coregonus peled*
Abramis brama	

4.5.4 Conclusions

A relatively large amount of information is available about introductions in the Former USSR, the Scandinavian countries (Norway, Sweden and Finland), Germany, Italy and France. In general introductions have been widespread throughout 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. Bighead and silver carps were introduced in the former USSR. Stocking of salmonids, coregonids, pike, pikeperch and perch is applied in various countries of Northern Europe. Grasscarp has also been released to control aquatic weeds in this continent.

5. ENVIRONMENTAL IMPACTS OF INLAND FISHERY ENHANCEMENTS

5.1 Introduction

5.1.1 Background and goal

One of the conclusions of the FAO/DFID Expert Consultation on Inland Fishery Enhancements (Dhaka, Bangladesh, 7 April 1997) was that applied research on impacts and mitigation measures of inland fisheries enhancements, including documentation and syntheses of experience, is urgently needed. In many areas, there may be a need to provide for environmental assessments of fishery enhancement activities, including aquaculture, which would help to identify potentially significant impacts and mechanisms for mitigation and rehabilitation.

The environmental impacts of fishery enhancements are now fully acknowledged by international organizations and various individual countries. This is reflected in a number of (recently) published guidelines and protocols on inland fishery enhancements containing specific paragraphs, procedures or rules on environmental issues. These include the Code of Conduct for Responsible Fisheries (FAO 1995), the FAO Technical Guidelines for Responsible Fisheries no. 2: Precautionary Approach to Capture Fisheries and Species Introductions (FAO 1996), the FAO Technical Guidelines for Responsible Fisheries no. 5: Aquaculture Development (FAO 1997a), the FAO Technical Guidelines for Responsible Fisheries no. 6: Inland Fisheries (FAO 1997c), the EIFAC/ICES Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms (Turner 1988) and the Code of Practice on the Introduction and Transfer of Marine Organisms, 1994 (ICES 1995). An overview is given in Garcia (1995). In addition to these general guidelines, there are a number of codes developed for specific species, for example the Guidelines for the stocking of coregonids (FAO 1994), and specific guidelines on Salmonids in the United States. On a national level several countries have developed national or regional strategies to prevent detrimental effects of fishery enhancements. For example a review of governmental views and regulations in Canada can be found in Leach and Lewis (1991), an overview of the US federal policies is given in Stanley *et al.* (1991) and Wingate (1991) gives a survey of policies in the individual US states. All of these codes and regulations give a broad direction towards control of fisheries enhancements, mainly on national and management levels. However, they do not include practical guidelines or instructions to be used when fishery enhancement activities are implemented. Also, they are focused mainly on introductions and stocking. Other enhancement activities like engineering the environment or elimination of unwanted species is not dealt with in detail. This paper therefore is a first attempt to overview the environmental impacts of fisheries enhancements and to assess the status of environmental studies in this field. The goal is to review what information exists, and what type of activities has been carried out so far. It was not the purpose to compile extended information in written text. Whenever relevant, references of key literature are given. The reader should turn to these references for detailed information.

5.1.2 Search strategy

Information was gathered by studying literature on inland fishery enhancements which is available at the Inland Water Resources and Aquaculture Service of the Fishery Resources Division at FAO Headquarters, Rome, and from articles and abstracts found in ASFA. As a basis for the ASFA search, the preliminary search made by A.F. Born for the database on

Fisheries Enhancements was used. The selections from this search were screened again for environmental topics. In the time frame of this study not all relevant ASFA literature could be checked, therefore this overview should by no means be regarded as complete. The main focus is on information about introductions, stocking, and genetic modification. Staff consulted from the service mentioned above were U.C. Barg, D.M. Bartley, A.F. Born, R.L. Welcomme and J.M. Kapetsky.

5.2 Environmental impacts and concomitant prevention, mitigation and rehabilitation measures

The potential environmental impacts of enhancement activities are described followed by possible prevention, mitigation and rehabilitation measures. A summary is given in an annotated matrix in Table 22, starting on the following page.

Three different ways to counteract detrimental environmental impacts are distinguished. *Prevention* is defined as a way to actively prevent negative environmental impacts occurring. *Mitigation* is regarded as 'lessening' environmental impacts and thus accepts that impacts will occur. These measures can also be taken outside the fisheries sector. *Rehabilitation* measures are taken to try to restore a system or situation once the negative effect of the fishery enhancement has already occurred or is already occurring.

5.2.1 Impacts of introductions

Predation
Predatory species can have direct and indirect impacts. Direct consumption of adults, fry or eggs results in an immediate decline of prey populations. Examples of indirect impacts are changes in distribution patterns and effects on the behavior of resident species. Both may lead to increased pressure on populations. For example, in several cases the increase of emigration rate of prey fish was reported to be at least as important in reducing the number of prey fish as direct consumption by its predators (He and Kitchell 1990, Crowl *et al.* 1992). An example of behavioral effects is prey fish altering their feeding patterns in the presence of fish predators. By restricting feeding time or selecting sub-optimal feeding locations, native fish then may suffer reduced growth rates and reproductive outputs (Crowl *et al.* 1992).

Creating shelter for prey, for example through planting of aquatic vegetation, could mitigate these effects. Another example is given by Chapman *et al.* (1996) who studied the potential of wetlands as structural and low-oxygen refuges for prey species of *Lates niloticus,* tolerant to that environment.

Competition
Native and introduced species can compete for different resources, like food and space (Krueger and May 1991, Twongo 1995). Competition for food is basically a diet overlap. As successfully introduced fishes typically exhibit generalistic feeding habits and trophic opportunism, there is consequently considerable overlap in the diets of introduced and indigenous fishes in many waterbodies (Arthington 1991). Competition for space includes spawning, breeding and nursery sites and shelter places. Competitive interactions may lead to the oppression or even extinction of populations and to niche shifts (Krueger and May 1991). Introductions into niches already filled by native species should therefore be avoided (Turner 1988).

Table 22: Annotated matrix of environmental impacts, prevention, mitigation and rehabilitation measures, per type of fishery enhancement

INTRODUCTIONS ***Environmental Impacts***	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures***
Predation	
• direct impact: direct consumption of adults, fry or eggs of other species • indirect impact: changes in patterns and behavioral effects[1]	• provide shelter for prey (P)
Competition[2]	
competition for food or space which may lead to: • oppression or extinction of populations • iche shifts	• avoid introduction into a niche already filled by a native species (P)[3]
Diseases[4]	
• introduction of new infectious diseases or parasites • when introduced fish are not resistant to an endemic disease or parasite, they may act as a reservoir for the proliferation of the disease	• health certification from exporter (P)[5] • use of hatcheries and quarantine stations (P)[5] • disease diagnostics (P)[5]
Habitat alteration	
• habitat degradation • changes in habitat use • water quality alterations [6]	• rehabilitation of degraded habitat (R) • creating (artificial) alternatives for lost habitat (M)
Genetic changes[7]	
• direct effects through hybridization and introgression: disruption of adaptive gene complexes of native species; reduction in fitness; reduction of the genetic variability • Indirect effects through altered selection regimes and reductions in population size: reduction of the genetic adaptability; reduced fitness	• genetic stock identification prior to the introduction (P)[8,9] • protect and preserve the genetic diversity of native species by establishing *reserves*, by artificially maintaining populations, or by cryopreservation of gametes or embryos (M)[9]
Accidental colonization of new waters	
• the above mentioned effects	• study of the watershed prior to the introduction (P) • installation of fish barriers (P)

[1] He and Kitchell (1990), Crowl et al. (1992); [2] Arthington (1991), Krueger and May (1991), Twongo (1995); [3] Turner (1988); [4] Stewart (1991), Cowx (1994); [5] FAO (1996), Turner (1988); [6] Holcík (1991); [7] Waples (1991), Krueger and May (1991), Gaffney and Allen (1992); [8] FAO (1996), Turner (1988); [9] Cowx (1994).

Table 22: continued

STOCKING ***Environmental Impacts***	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures***
Genetic changes see "Introductions:" dilution of genetic variation and risks for genetic stability of stocked and native populations, reduced fitness	• limit possible effects of selection within the hatchery (adaptation to domestication) by avoiding stocked fish reared in captivity for more than one generation (P)[9] • minimize genetic impact on wild stocks by stocking fish from breeding programs that deliberately generate genetic diversity (P)[10] • use of sterile or non-breeding organisms to reduce the chance of interbreeding with natural fish stocks (P)[11] • develop stocks specifically adapted to the local environment (P)[10] • use of stock from a waterbody with a similar use sufficient fish for broodstock to avoid reducing the genetic variability (P)[9] • obtain stock from a number of sources to maximize the range of genetic material (P)[9] • build up of stock by hatchery production based entirely on local stock (if available) and return brood stock to home system (P)[9] • redistribution of adults from elsewhere in the catchment (P)[9]
Overstocking • reduced growth rate[9, 12] • increased mortality rates[9] • inhibition of natural production[12]	• population control of stocked species (R) • providing extra resources (M) • avoid stocking during natural spawning period (P)[9]
Predation[9] see introductions	see introductions
Competition[9] see introductions	• release by scatter or trickle planting instead of spot planting (P)[9]
Diseases • transmission with the transfer of stocks between waterbodies	see introductions
Reduction of wild populations through extracting large numbers of young fish from lakes, rivers, and marine coastal areas for stocking[13]	• regular monitoring of densities; develop quota when necessary (P)
Impacts associated with hatchery production when using seed from aquaculture for stocking	• environmentally sound management of aquaculture production system (P)

[9] Cowx (1994); [10] Doyle et al. (1991); [11] Turner (1988), FAO (1996); [12] Welcomme and Bartley (1998); [13] Welcomme (1998)

Table 22: continued

GENETIC MODIFICATION ***Environmental Impacts*** • impacts similar but possibly exacerbated as those of introductions and stocking with non-transgenic cultured fish[12]	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** • see introductions and stocking • minimize the risk of escape through type of culture facility (P)[12]
FERTILIZATION ***Environmental Impacts*** • changes in water quality, eutrophication and cascading community effects when nutrient inputs exceed the carrying capacity of the habitat[13] • health risks for people involved when applying manure or waste (water) • introduction of diseases through the use of manure or waste (water)	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** • regular water quality monitoring and adjustment of fertilizer doses when necessary (P) • check composition or origin of wastes before use (P) • use of protection measures and inform people on how to avoid risks (P) • check composition or origin of waste (water) before use (P)
ENGINEERING THE ENVIRONMENT ***Environmental Impacts*** • habitat alterations which may lead to secondary effects on fauna and flora, see introductions	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** see introductions
ELIMINATION OF UNWANTED SPECIES ***Environmental Impacts*** • non-selective methods eliminate other species of fauna and flora as well when introducing or stocking with predators or competitors for elimination: see introduction and stocking	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** • re-introduction of species (R) • creation of refuge (M) see introductions and stocking
CONSTITUTING AN ARTIFICIAL FAUNA ***Environmental Impacts*** when new species are used: see introductions	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** see introductions
MODIFICATION OF WATER BODIES ***Environmental Impacts*** • habitat alterations which may lead to secondary effects on native fauna and flora, see introductions • water quality alterations	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** see introductions water quality monitoring to take measures when necessary (M, R)
CAGE CULTURE AND PARALLEL INTENSIFICATION OF EFFORT OF CAPTURE FISHERIES ***Environmental Impacts*** • negative impacts associated with aquaculture • introduction of diseases: see introductions • effects caused by escaped fish: see introductions	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** • environmentally sound management of cage culture system (P) see introductions see introductions
AQUACULTURE / MANAGEMENT AS INTENSIVE FISH PONDS ***Environmental Impacts*** • negative impacts associated with aquaculture • effects caused by escaped fish: see impacts of introductions and stocking	***Prevention (P) / Mitigation (M) / Rehabilitation (R) measures*** • environmentally sound management of aquaculture system (P) see introductions and stocking

[12] Kapuscinski and Hallerman(1990) and (Hallerman and Kapuscinski (1992); [13] Coates (1995)

Diseases

Introduction of new species can lead to the concomitant introduction of new infectious diseases and parasites affecting native species (Stewart 1991). Conversely, when introduced species are not resistant to an endemic disease or parasite, they may act as a reservoir for the proliferation of the disease (Cowx 1994).

Health certification from the exporter, disease diagnostics to monitor the health of introduced species prior to release and the use of hatcheries and quarantine stations may reduce the chances of spreading of diseases and impart some control on the numbers of exotic diseases released. (FAO 1996, Turner 1998).

Habitat alterations

Habitat alterations due to introductions can occur in various ways: introduced species can cause physical changes degrading the habitat, changes in habitat use can occur, and the water quality may change (Holcík 1991). An example of habitat degradation is that introduced species may feed on submerged macrophytes which serve as spawning habitat for native species or which form cover for juvenile fish and invertebrate food organisms. Krueger and May (1991) report on the potential effects of salmonids digging redds in the stream bottom for incubation of their eggs. Possible impacts could be the reduction of invertebrate production through dislodgment or destruction; disturbance of redds of native salmon, which spawn at the same time of the year, disruption of habitat for other fish species, or physical destruction of eggs of other species. An example of changes in habitat use is given by Braband and Faafeng (1993): introduction of pikeperch resulted in a decreasing density of juvenile roach in pelagic areas. Subsequently, this loss of pelagic refuge increased the availability of juvenile roach to littoral predators. A well known example of water quality alteration is the increase in turbidity through the feeding activity of introduced carp (Bales 1992, Moyle *et al.* 1986, Taylor *et al.* 1984, Dunn 1994). It may lead to decreased efficiency of visually feeding predators or could affect primary production (Ramos-Henao and Corredor 1978, Dunn 1994).

Habitat alterations might be reversed through rehabilitation measures, which restore the habitat (for example re-planting of macrophytes) if repetition of the damage can be avoided. If not, alternatives might be developed for the affected species, like creating artificial shelter places.

Genetic changes

Introduction of new species to an area might lead to changes in, or damage to, the genetic composition of both the resident and the introduced species. Direct and indirect genetic impacts can be distinguished (Waples 1991, Krueger and May 1991, Gaffney and Allen 1992). Direct genetic effects are caused by hybridization and introgression through interbreeding of native and introduced species. Disruption of the adaptive gene complexes which permit native species to effectively use its particular environmental niche, reduction in fitness (outbreeding depression) and reduction of the genetic variability may result (Krueger and May 1991, Waples 1991). Indirect effects are due to altered selection regimes or reductions in population size resulting from ecological interactions (for example competition, predation or disease introductions) between introduced and native organisms. Again a reduction of the genetic adaptability and reduced fitness may be the result (Krueger and May 1991). It is important to mention here that translocations of species that closely match population characteristics of the native stock can have, due to easier hybridization, more severe impacts than introductions of entirely alien genera (Carvalho & Hauser 1995).

Genetic stock identification prior to the introduction can help to reduce or prevent changes in the fishery resource (FAO 1996, Turner 1988). Furthermore, the genetic diversity of native or threatened species can be protected and preserved by establishing 'reserves' (areas where introductions, stocking and transfers are forbidden), by artificially maintaining populations and by cryopreservation of gametes or embryos (Turner 1988).

Colonization of new waters

When introducing species into a water body there is a distinct risk that these species spread out to other waters where the introduction was not intended. A study of the whole watershed prior to the introduction can reveal possible ways through which fish might migrate (contiguous rivers, tributaries, and lakes). Installing devices like screens can then prevent migration of the introduced species. Also construction works may alter waterbodies, creating new routes or destroying physical structures previously functioning as fish barriers. For example, to prevent accidental introduction of exotics in the Great Lakes, environmental impact studies are now required prior to construction of diversions and canals (Dochoda *et al.* 1989).

It should be noted that predation, habitat alteration, competition and diseases not only affect native fish species but may also affect invertebrates, amphibians, aquatic flora, etc. Disturbances of these populations may then again lead to increased pressure on native fish.

5.2.2 Impacts of stocking

Predation

Stocking, as with the introduction of species, can have undesirable effects on endemic fish through predation (Cowx 1994).

Competition

Stocking, as with the introduction of species, can have undesirable effects on endemic fish through competition (Cowx 1994). The way of releasing fish can play a role in minimizing competitive pressure: release by scatter planting, which is releasing fish into several sites in the same region, or trickle planting, releasing fish in the same region over a period of time, will reduce competitive pressure compared to spot planting when all fish are released at the same site (Cowx 1994).

Diseases

Diseases can be transmitted through the transfer of seed from hatcheries to open waters. Hatcheries may serve as reservoirs for diseases if not properly managed. Preventive measures can be achieved through good hatchery management and are furthermore described in the section introductions (5.2.1).

Genetic changes

Stocking, as with the introduction of species, can cause dilution of the genetic variation and may change the genetic stability of stocked and native populations, especially when stocking with fish of unknown origin (Cowx 1994).

Measures to minimize the dilution of genetic variation are:

- limit possible effects of selection within the hatchery (adaptation to domestication) by avoiding stocked fish reared in captivity for more than one generation (Cowx 1994)
- minimize genetic impact on wild stocks by stocking fish from breeding programs that deliberately generate genetic diversity (Doyle *et al.* 1991)

- use of sterile or non-breeding organisms to reduce the chance of interbreeding with natural fish stocks (Turner 1988, FAO 1996)
- develop stocks specifically adapted to the local environment (Doyle *et al.* 1991)
- use of stock from a waterbody with a similar environment (Cowx 1994)
- use sufficient fish for broodstock to avoid reducing the genetic variability (Cowx 1994)
- obtain stock from a number of sources to maximize the range of genetic material (Cowx 1994)
- build up of stock by hatchery production based entirely on local stock (if available) and return brood stock to home system (Cowx 1994)
- redistribution of adults from elsewhere in the catchment (Cowx 1994)

Overstocking

Especially when fish are stocked into populations where natural reproduction occurs as well, there is a danger of overstocking. When the number of fish exceeds the carrying capacity of the habitat, at a certain exploitation rate, density dependent factors such as food availability may limit growth and the initial increase in fish density may be counteracted through increased mortality rates (Cowx 1994, Welcomme and Bartley 1998). The stocking density that will achieve a particular carrying capacity will depend on the exploitation of the stocked population - a high level of exploitation calls for high stocking densities and vice versa (see figure in Lorenzen 1995). Optimal stocking density therefore depends on the pattern of exploitation. Furthermore, natural reproduction may be inhibited when the fish used for stocking are not adapted to the recipient water body (Welcomme and Bartley 1998). Overstocking is indeed common as found in a study of small water body fisheries in Thailand (Lorenzen *et al.* 1998a) where about 50% of village fisheries were overstocked.

Up to a certain extent the problems of overstocking can be met by providing extra resources, for example through fertilization or providing extra space or shelter but as well by choosing the proper combination of stocking densities and exploitation rates (see Lorenzen 1995). Population control of stocked species can also be accomplished through, for example, selective catch. Stocking during natural spawning periods should be avoided to minimize density dependent effects on the juveniles (Cowx 1994, see also “competition”).

Reduction of wild populations

When seed from wild populations is used for stocking, the sustainability of natural stocks can be damaged through the extraction of large numbers of young fish from lakes, rivers, and marine coastal areas (Welcomme 1998). Regular monitoring of densities can help to avoid over-fishing and provides data to develop quota when necessary.

Environmental impacts associated with hatchery production

When seed from artificial reproduction is used for stocking, environmental impacts can occur due to the hatchery activities, for example pollution through the use pharmaceuticals. Through environmentally sound management of the hatchery facilities, these impacts can be prevented.

5.2.3 Impacts of genetic modification

Environmental impacts associated with the release of transgenic fish include those of introductions and stocking with normal hatchery-reared or wild transplanted stocks. Information on impacts, specifically with regard to transgenity, is scarce as to date relatively few structural genes have been successfully transferred, little is known about the performance of genetically modified fish, and large scale application of genetic modified fish is not yet carried out.

Kapuscinski and Hallerman (1990) state that the major determinant of ecological impacts of transgenic fish is the phenotypic change brought about by the genetic modification. The impacts will result from altered performance of such fish. For example, increased growth rates of fish through transfer of growth hormone genes may affect several components of the energy budget of the fish, such as consumption rates or waste losses. This might then affect for example water quality or food availability. The phenotypic changes may also exacerbate the impacts caused by introductions and stocking; fish that grow faster may cause more severe forms of competition. Next to the phenotypic changes also genetic mechanisms may intensify the impacts of non-transgenic introduced or stocked fish, namely when reproduction in the wild occurs (Hallerman and Kapuscinski (1992).

An overview of phenotypic changes, genetic mechanisms and their possible impacts is given in Kapuscinski and Hallerman (1990) and Hallerman and Kapuscinski (1992). The US Department of Agriculture, Agricultural Biotechnology Research Advisory Committee, issued through a working group on Aquatic Biotechnology and Environmental Safety performance standards for safely conducting research with genetically modified fish and shellfish (USDA 1995). In Hallerman and Kapuscinski (1995) an overview of national policies on aquatic genetically modified organisms in the USA, Canada, Norway, UK and other countries is given.

The risk of environmental impacts is to a large degree determined by the risk of genetically modified fish escaping from aquaculture facilities. Therefore the method of containment of fish is an important factor in reducing the risk (for example indoor systems vs. outdoor culture) (Hallerman and Kapuscinski 1992).

5.2.4 Impacts of fertilization

Inorganic fertilizers, organic material, agricultural wastes, waste water and fish feeds are applied for fertilization. When the nutrient input exceeds the carrying capacity of the water, pollution problems result (Coates 1995). Changes in water quality, eutrophication and cascading community effects may result. Especially when wastes of unknown composition or origin are used the risk of water and even soil pollution is high. The use of wastes or manure may cause spreading of diseases and involves health risks for people involved in the fisheries activities.

Through regular water quality monitoring fertilizer doses can be adjusted. The composition or origin of wastes should be checked before use. Informing people involved in the work and the use of protection measures when applying fertilizers reduces the health risks.

5.2.5 Impacts of engineering the environment

Engineering of the environment mainly comprises habitat modifications, for example regulation of water levels, installation of fish passes or construction of spawning places, some of which may lead to secondary negative effects on native fauna and flora. The impacts and concomitant preventive, mitigation or rehabilitation measures include those described with habitat alterations caused through introductions.

5.2.6 Impacts of elimination of unwanted species

Elimination of unwanted species can be carried out through heavy fishing (using nets, traps, electric fishing), through poisoning the water body before stocking (rotenone, antimycin), through complete draining of the water body before filling and stocking or through introduction or stocking with predatory or competing species. Although depending on the way the techniques are performed, they are generally speaking non-selective methods with a high risk of eliminating other species of fauna and flora as well. It thus constitutes a potential risk of threat to biodiversity. The technique of using predatory or competing species to eliminate other species also holds the risk associated with introduction and stocking as described above. Selective fishing, creating of refuges and re-introduction of (desired) species can counteract the effects.

5.2.7 Impacts of constituting an artificial fauna

When new species are used to create an artificial fauna, the impacts are similar to those described in introductions. ‘New species’ relates to the direct input of new fish species as well as to the introduction of new or better-adapted food organisms. A well-documented example of the latter is the introduction of *Mysis relicta* (Morgan *et al.* 1978, Goldman *et al.* 1979, Garnaas 1986, Hammer 1988, Martinez and Bergersen 1989 and Thompson *et al.* 1995). The opossum shrimp is introduced to supplement the prey bases for certain fish species, but its predation on zooplankton has resulted in diminished food for other fish species.

5.2.8 Impacts of modification of waterbodies

The modification of waterbodies leads to habitat alterations and may influence water quality. For example, when cutting a bay to increase the control on fish production, a reduction of water circulation may result. Impacts and preventive measures are similar to the habitat alterations caused by introductions.

5.2.9 Impacts of cage culture and parallel intensification of effort of capture fisheries

The impacts of cage culture include those associated with aquaculture, for example eutrophication through fish feed. Other impacts are the introduction of diseases and impacts caused by escaped fish. Both are similar to the effects and measures described with introductions and stocking.

5.2.10 Impacts of aquaculture and management as intensive fish ponds

Negative impacts due to aquaculture production are water pollution through fish feed and the use of pharmaceuticals, the introduction of diseases, etc. Furthermore the number of fish escaping from a production-scale aquaculture facility can be considerable: although that does not automatically mean that viable populations of escaped species will develop, it is possible. Therefore impacts associated with stocking and introduction should also be considered here.

Improved containment to reduce the percentage of fish escaping (although total elimination of escapes is not likely) can help to minimize the impacts.

5.3 Status of environmental studies

Most literature originates from the USA, Canada, Australia, New Zealand, Northern and Western Europe and, to a lesser extent, from the former USSR and other East European countries. Information from developing countries is limited but as it is mainly derived from development aid projects often provide interesting data based on concrete activities instead of being based on theoretical studies. In order to get an overview, the information found is sorted into three groups: 'General Studies,' 'Tools for Environmental Studies,' and 'Environmental Assessments.'

5.3.1 General studies (post-intervention)

Most articles on the environmental impacts of fisheries enhancements are very general. The information given is restricted to an account or observation of the impact after the intervention has occurred, describing for example predation or changes in species composition. They are based on literature (e.g. by comparing pre-and post-project data.) and on field observations. On the effects of introductions for example, the ASFA search revealed more then 200 references, of which at least 90 report on predation.

5.3.2 Tools for environmental assessments

These types of studies are too limited to be regarded as complete environmental assessments as defined in 5.3.3, but may be an important aid to develop them, i.e. they can be used as tools for Environmental Assessments.

Pilot studies
Several articles describe experiments in which the effects of enhancements are tested on a limited scale. Berg *et al.* (1994) and Jones and Stanfield (1993) analyze the environmental effects of introductions by setting up experiments in confined waterbodies. Philipp (1991) uses experimental populations (original species and their hybrids) to examine the genetic implications of introductions. Pilot studies on the effects of competition are reviewed by Krueger and May (1991).

Results from these pilot studies allow conclusions to be drawn on environmental impacts of enhancements, although extrapolation to the natural environment is not always possible due to the specific conditions of the experiments. Pilot studies often have to be simplified in design and time frame, and are conducted under comparatively artificial conditions due to logistical practicality (Krueger and May 1991).

Theoretical models
Several theoretical models have been developed which can be used to predict environmental impacts of fishery enhancements. Like pilot studies, they can be used when carrying out Environmental Assessments. A limiting factor may be that they usually require a lot of data, which in practice may not always be available.

Examples in literature are: a simulation model to examine the effect of rainbow trout introduction in Lake Washington (Swartzman and Beauchamp 1990); loop-analysis (a tool of system analysis) used by Li and Moyle (1981); Ecopath II, a multi-species model to analyze the effects of introductions, described by Moreau (1997); and in Arthington (1991) several references are given on an ecological approach to predict the outcome of fish introductions (Arthington and Mitchell 1986), Li and Moyle 1981, Moyle *et al.* 1986). There is also a simple model by Coates & Ulaiwi (1995), predicting the potential impact of introductions based on elementary niche classification of the introduced and indigenous species.

Checklists and protocols
In Environmental Assessments often checklists or protocols are used. Bain (1993) developed a checklist to assess the impacts of introduced species. It consists of six categories of impact indicators. The potential impact can then be estimated by analyzing for each indicator the vulnerability of the species or habitat involved. In Kohler and Stanley (1984) a protocol is suggested for evaluating proposed exotic fish introductions in the United States. This method was used in practice to assess the impact of introductions in Northeast Thailand (De Iongh and Van Zon 1993), and in Mozambique (Bartley 1993, Impacto 1997). Both cases are summarized in Table 23. Kohler (1992) presents a method for environmental risk assessment of introductions based on: 1) the risk that species might escape 2) the risk that escaped species acclimate to the natural environment 3) the vulnerability of a receiving system 4) the threat potential of the introduced species. In Riggs (1986 and 1990) a framework for the evaluation of stocking with hatchery reared fish is designed with emphasis on the conservation of genetic resources of natural populations. Li and Moyle (1981) point out that protocols developed by entomologists to guide selection of predators for biological control systems can be adapted for fisheries management, more specifically for introductions.

5.3.3 Environmental assessments (pre-intervention)

Various definitions are used in literature to describe environmental studies, and confusion exists on the use of terms like risk assessment, impact assessment, environmental appraisal, environmental assessment, etc. (Barg 1992). Therefore in this paper the general term *'environmental assessment'* is used. In general, environmental assessments are used as *predictive* tools. They are carried out ***before*** an activity is started, or even before it is decided what type of activity (what type of enhancement) will be carried out. In environmental assessments potential environmental impacts are reviewed and evaluated in order to take them into account from the very beginning of an activity. An important aspect of environmental assessments is that they include recommendations on how to prevent or mitigate potential environmental impacts. Examples of environmental assessments are environmental impact assessments and environmental risk assessments.

Environmental assessments, like environmental impact assessments and environmental risk assessments, which analyze an enhancement activity as a whole and which start in the planning phase of the enhancement, were found to be scarce. The examples found are given in Table 23. In addition, ICES regularly evaluates proposed introductions on request of its member countries. Despite the low number of examples found, it is expected that in practice many more environmental assessments have been carried out. As described in the introduction (see 5.1), various countries already have developed national legislation on environmental impacts of fishery enhancements. This legislation often includes the requirement of risk and impact assessments before approval is given to start enhancement activities (for example Shafland 1986, Drinnan, 1988, Dochoda *et al.* 1989). Therefore other sources of information need to be checked in addition to scientific literature.

Table 23: Environmental Assessments*

Type of study (source)	**Type of enhancement**	**Location**	**Organization**
Environmental Assessment (Bartley 1993, Impacto 1997)	Culture of introduced species in coastal barrier lakes	Mozambique: Gaza Province, Chidenguele lakes	Alcom; Dept. of Fish Aquaculture, Ministry of Agriculture
Environmental Impact Assessment (Townsend and Winterbourn 1991)	Introduction for aquaculture	New Zealand	Ministry of Fisheries
Environmental Assessment based on the ICES/EIFAC Codes of Practice (FAO 1997b)	Introduction / Stocking	Papua New Guinea: Sepik-Ramu River basin	FAO / UNDP / PNG
Assessment of ecological impact of introductions (De Iongh and van Zon 1993)	Introduction	Thailand: north east	Center of Environmental Science, Leiden, The Netherlands

***Note: this table is continuous across both pages**

Species	Summary	Prevention / Mitigation / Rehabilitation
Chinese carp	An environmental assessment was carried out based on a basic ecological evaluation of the habitat and application of the ICES/EIFAC Codes of Practice.	Based on the use of the code, the introduction is not recommended
Ictalurus punctatus, channel catfish	An environmental impact assessment was carried out regarding the proposed introduction of channel catfish to New Zealand for aquaculture. It incorporated details of channel catfish biology, its value to people, diseases, the history of introductions elsewhere and possible impacts on New Zealand biota should species become established in the wild.	The outcome of the EIA indicated that one or more valued species was likely to suffer a decline if channel catfish were introduced. The environmental risk posed by the fish was therefore concluded to be unacceptable and the planned introduction was cancelled.
Tilapia rendalli, *Osphronemus gouramy, Trichogaster pectoralis, Puntius gonionotus, Prochilodus margravii, Colossoma bidens, Tor putitora, Acrossocheilus hexagonolepis, Schizothorax richardsonii, Labeo dero*	Prior to the introduction and stocking of the new and transferred species, the species were evaluated on the basis of the ' Codes of practice and manual of procedures for consideration of introductions and transfers of marine and freshwater organisms', from EIFAC (Turner 1988). Part of this procedure involves soliciting independent views from the project Advisory Group. Each species was also evaluated via the PNG internal review mechanisms, which included consultations with the Department of Environment and Conservation. Socio-economic aspects of the introductions were considered	Species evaluation based on Code of Practice
Cyprinus carpio, Oreochromis niloticus, Chinese and Indian carps	An assessment of the ecological impacts was carried out using the protocol of Kohler and Stanley (1984), covering feasibility of introduction, acclimatization potential, potential impact, and control potentials. Outcome: no severe ecological impact in terms of deterioration of aquatic ecosystems; incidental cases of minor ecological impacts were reported for common carp and Nile tilapia; indications for niche competition between Chinese and Indian carps and indigenous carps; niche competition for bighead carp, *Aristichthys nobilis*, and indigenous pelagic zooplankton feeders. Socio-economic aspects of the introductions. were considered	Observing the prolific development of the Nile tilapia in a number of reported cases, it was recommended not to include this species until more risk assessments are available

5.4 Technical, administrative, social and economic aspects of environmental impacts

One of the objectives of this study was to identify technical, administrative, social and economic aspects of environmental impacts. Given the limited information found on environmental studies in general, it is clear that also these more specific data are scarce. Two of the studies include socio-economic aspects. No more relevant literature on the subject was found. However, studies in which socio-economic aspects of enhancements in general are analyzed, might include aspects, which are mainly attributed to environmental changes. Therefore it is recommended for future research to check these sources.

5.5 Constraints in the assessment of environmental impacts

Information on the type and degree of environmental impacts associated with fisheries enhancements is essential before fisheries managers and policy makers make any decisions on the implementation of such activities. To date, these decisions are not always based on objective facts. Coates (1994) gives an example of Australia, where prejudice against certain exotic species resulted in considerable translocation of native species for stocking reservoirs, with limited attention to the potential effects on the genetic composition of native stocks. According to the author translocation of indigenous species or strains could be more damaging to biodiversity than the use of exotics, since it is inevitable that a loss of local strains through hybridization will result from most transfers. Also Crossman (1991) states that, compared to 'real' exotics (release of species outside their present range), introductions of transplanted fishes (release of species within their present range) in North America has been treated with far less concern without there being an objective reason to do so. These examples illustrate the need of objective information. However, a number of constraints in the assessment of environmental impacts exist. Aspects playing a major role are pointed out in the following paragraphs:

A major constraint is the lack of data. In order to assess environmental impacts, data on pre- and post abundances and disturbances in the aquatic environment are essential. Often data on the initial situation are lacking. Scarce knowledge of the biology of native species can also be one of the causes of the difficulty to understand the mechanisms of interactions between native and introduced species (Rodriguez-Gomez 1989). Alternately, many enhancements are conducted in relatively small water bodies of which there are usually many replicates. This provides an excellent opportunity for spatial replication and controls, without the need to have pre-intervention data. Such an approach to assess stocking impacts on SWB fisheries in Laos was used by Lorenzen *et al.* (1998b). Spatial replication (i.e. comparison of stocked and non-stocked water bodies, with sufficient replicates) has tremendous potential for impact studies, which should perhaps be more widely recognized.

Secondly it is often difficult to distinguish between impacts caused by enhancements and impacts caused by external factors. An example is the discussion about the introduction of Nile perch in Lake Victoria. In early literature the decline of the haplochromine population was attributed almost completely to predation by Nile perch. Only later it became clear that increased eutrophication through pollution and over-exploitation may have played an important role as well (Pitcher and Hart 1995). Also effects of human-induced habitat deterioration, for example deforestation and swamp drainage, are hard to distinguish from inter-specific interactions, for example predation (McDowall 1990). The difficulty is compounded by the fact that introduced species are often more successful in (already) disturbed habitats (Shafland 1986 and Arthington 1991). A third example is the introduction of diseases, which may be caused by different factors that cannot easily be separated. Exotic fish for example, may introduce parasites but many fish parasites also have stages in birds. Bird migration across wide areas may then cause new areas to be invaded (Fernando 1991).

Another difficulty in assessing the impacts of enhancements is that not all impacts are equally easy to detect. A huge amount of literature is available on changes in species composition through predation, but this does not necessarily mean that predatorial behavior is the main impact of species introductions. It is much easier to detect than genetic effects for example. For the latter it may not even always be clear what symptoms have to be looked for. (See Allendorf 1991, Hallerman and Kapuscinsky 1992 and Gaffney and Allen 1992).

Finally, many enhancements go hand in hand with institutional changes, which may "feed back" and lead to unexpected technical and environmental outcomes (Lorenzen & Garaway 1998). This aspect deserves more attention at the appraisal stage. For example, tilapia stocking was found instrumental in the establishment of community management systems in Laos and in turn led to a drastic reduction in the previously very high levels of fishing effort (and the demise of destructive fishing methods). Consequently a threefold increase in the abundance of wild fish (relative to non-stocked, open access fisheries) was observed (Lorenzen *et al.* 1998 b). No significant impact on the diversity of wild stocks was found in this study, but the test used had a low statistical power and the possibility that significant impacts may exist could not be ruled out.

5.6 Recommendations for further desk studies

The ASFA search resulted in an extensive compilation of articles, all of which could not be reviewed in the time frame of this study. Main attention was focused on Introductions, Stocking and Genetic Modification. The review of literature on these three topics should be continued and in addition, literature on the environmental impacts of other types of enhancements should be reviewed.

As pointed out in 5.3 “Status of environmental studies,” the lack of examples found of environmental assessment studies carried out in practice could be caused by the fact that they are not (yet) described in scientific literature. It might be interesting to search for information via other sources, e.g. consultant firms carrying out this type of studies or national organizations involved in fishery policies and legislation. These sources might also reveal more information on prevention, mitigation and rehabilitation measures, which have been carried out.

6. EVALUATION OF THE APPLIED SEARCH METHOD

The followed method is useful as a first step into the characterization of enhancements. The method heavily relies on the ASFA literature and other sources should be included in the future. The computerized searches and the automated building of the database made it possible to screen a large number of references, which are stored and categorized in an easily accessible spreadsheet and database. They can easily be used for further reference in fishery enhancement studies.

The characterization is based on literature information in ASFA. Developing countries are likely to contribute to a lesser extent to the scientific literature than do developed countries. This may partly explain the smaller numbers of enhancement literature in Africa, Asia, Oceania and Latin America. It should therefore be kept in mind that this study is an overview of the available information in ASFA and does not give a relative importance of enhancement activities and efforts in the various countries which are often not documented or not present in the scientific literature. The additional information provided by the Hatchery Production Data and by the Data on Introductions of Aquatic Species was instrumental to point out the gaps.

6.1 Asia, Oceania, Africa and Latin America

The accuracy of the method for Asia, Oceania, Africa and Latin America was tested by comparing the total number of references from the searches and the relevant number of references after reading the abstracts. The results are given in Table 24 and Table 25. About 15% of the downloaded references were considered relevant for the database. Discarded abstracts were dealing with aquaculture, limnological and ecological studies. Proposals for enhancements were only mentioned briefly or were not the main issue of the paper. Though some of these abstracts could be interesting for further reading and give valuable ideas and descriptions, they were not detailed enough to be used in the database.

Table 24: Number of references and relevant references

Search	# References	# Relevant	% Relevant
Africa, introductions	243	55	22.6
Africa, stocking	165	59	24.3
Africa, env. engineering	55	5	9.1
Asia, introductions	390	38	9.7
Asia, stocking	1033	172	16.7
Asia, env. engineering	334	13	38.9
South America, introductions	103	11	10.7
South America, stocking	153	19	12.4
South America, env. Eng.	21	0	0
Central America, introductions	86	3	3.5
Central America, stocking	70	9	12.9
Central America, env. Eng.	37	1	2.7
Oceania, introductions	308	55	17.9
Oceania, stocking	159	32	20.1
Oceania, env. engineering	65	3	4.6
World, fertilization	301	21	7.0
Total	**3523**	**496**	**14.1**

Table 25: Number of references and relevant references per enhancement type

Profile Category	# References	# Relevant	% Relevant
Engineering	512	22	4.2
Fertilization	301	21	7.0
Introductions	1130	162	14.3
Stocking	1580	291	18.4
Total	**3523**	**496**	**14.1**

6.2 North America and Europe

The information that was selected with the searches for key terms in the descriptor fields (see Table 26) was cross-checked with the contents of the abstracts. For this purpose a sub-sample of 70 randomly selected references for North America were used. The results of the evaluation are given in Table 26. Countries, water bodies and enhancement types were identified for 100%, 85% and 84% respectively. The purpose of enhancements was difficult to characterize with the descriptor terms only. Purposes such as sport fisheries, aquatic weed control, restoration could be identified properly but others can only be identified after reading the abstracts.

Table 26: Evaluation of selected references for a sub-sample of North America

Item	Number tested	Right	Wrong	Not Sure	Not Identified
Enhancement type	70	59 (84%)	4	2	5
Country	70	70 (100%)	0	0	0
Water body	70	60 (85%)	2	1	7
Purpose of enhancement	70	21 (30%)	46	0	3

The selection of species was enhanced considerably through the followed method, compared to manual selection. The disadvantage of this method is that the species that are mentioned in a reference are not always the species that are stocked or introduced. Many references deal with the effects of introductions on other species for example. This bias only can be eliminated through careful screening of the abstracts.

7. CONCLUSIONS

- Global characterization of fishery enhancements based on the information in ASFA abstracts is effective for classification of enhancement types, water body types and countries but less accurate for enhancement purposes and evaluation of success/failure as these require more in depth analysis.

- Of the investigated enhancements (i.e. introductions, stocking, environmental engineering and fertilization), 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, restoration of floodplain-river connections and construction of appropriate fishways to fit the specific migration behavior of the individual migratory species are used and often with considerable success but evaluations and reviews 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 fertilization of inland water bodies as an enhancement technique is very scarce on a global scale, especially for larger water bodies.

- Enhancement techniques within the regions Africa, Latin America, Oceania and Asia are most diverse in Asia.

- Globally, introductions of Mozambique tilapia, common carp, and rainbow trout, Nile tilapia an brook/sea trout have been important to enhance the production of fish as a food and income source.

- Introductions of tilapias have been relatively successful in large water bodies due to the fact that this species establishes self-reproducing populations. Though regular stocking of this species is practiced worldwide, probably because large numbers can easily be produced in hatcheries without sophisticated techniques, it is in many cases not clear if such stocking programs significantly enhance fishery yields.

- Translocations and stocking of indigenous species have been effective measures 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 practices are least widespread in Africa, introductions are however relatively important in this continent.

- The available information on stocking and introductions in North America and Europe, 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 secondary importance is enhancement for recreational fisheries.

- Pre-intervention environmental assessments of inland fishery enhancements were found to be very scarce, but post-intervention studies are numerous, with a considerable amount of literature on the effects of predation by introduced species.

8. RECOMMENDATIONS

- The existing database for Africa, Asia, Oceania and Latin America should be extended to Europe and North America. This means that the rough classification done for Europe and North America should be refined by reading the abstracts and entering the classifications (enhancement types, purposes etc.).

- This overview is based on ASFA abstracts. It is recommended to research other information sources/databases, such as grey literature and project documents.

- Further analysis of environmental engineering and other enhancements in North America and Europe is needed. The searches so far focussed on stocking and introductions in these regions and the work should be further expanded to include other enhancements, of which habitat modifications and environmental engineering are probably most important.

- Environmental engineering closely relates to rehabilitation and restoration of fisheries (e.g. in response to dam construction) and these aspects could be well included in the database.

- Processing of the ASFA references for other enhancements than introductions, stocking, environmental engineering and fertilization such as for cage culture should be developed.

- The FAO hatchery production statistics could be further improved to be able to make more reliable production estimates. These data provide an excellent opportunity to analyze trends of stocking and to check on information found in the literature on stocking.

- Assessment of benefits and success/failure of enhancements requires an in-depth analysis. The information in the abstracts only is not sufficient to do such an analysis. The present characterization offers the starting point for a selection of a more detailed study on the benefits and evaluation of enhancement practices.

- Quantification of benefits of enhancements in terms of additional fishery yield should be further developed with, as a starting point the results of the present study, the fishery enhancement database and the lakes and rivers fishery database prepared by MRAG Ltd.

- Literature on the environmental impacts of other types of enhancements than introductions, stocking and genetic modification should be reviewed.

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Annex 1: Search Profiles

Africa.his

1 Africa
2 Ase
3 Algeria
4 Angola
5 Benin
6 Botswana
7 Burkina
8 Faso
9 Africa or Ase or Algeria or Angola or Benin or Botswana or Burkina Faso
10 Burundi
11 Cameroon
12 Cape
13 Verde
14 Central
15 Africa*
16 Chad
17 Comoros
18 Congo
19 .#9 or Burundi or Cameroon or Cape Verde or Central Africa* or Chad or Comoros or Congo
20 Cote
21 D¡Voire
22 Ivory
23 Coast
24 Djibouti
25 Egypt
26 Equatorial
27 Guinea
28 Ethiopia
29 .#19 or Cote D¡Voire or Ivory Coast or Djibouti or Egypt or Equatorial Guinea or Ethiopia
30 Gabon
31 Gambia
32 Ghana
33 Guinea
34 Kenya
35 Lake
36 Victoria
37 .#29 or Gabon or Gambia or Ghana or Guinea or Kenya or Lake Victoria
38 Lesotho
39 Liberia
40 Libya*
41 Madagascar
42 Malagasy
43 Malawi
44 Mali
45 .#37 or Lesotho or Liberia or Libya* or Madagascar or Malagasy or Malawi or Mali
46 Mauritania
47 Mauritius
48 Morocco
49 Mozambique
50 Namibia
51 Niger
52 Nigeria
53 .#45 or Mauritania or Mauritius or Morocco or Mozambique or Namibia or Niger or Nigeria
54 Rwanda
55 Sahara
56 Sahel
57 Sao
58 Tome
59 Senegal
60 Sierra
61 Leone
62 Seychelles
63 Somalia
64 South
65 Africa
66 .#53 or Rwanda or Sahara or Sahel or Sao Tome or Senegal or Sierra Leone or Seychelles or Somalia or South Africa
67 Sudan
68 Swaziland
69 Tanzania
70 Togo
71 Tunisia
72 Uganda
73 Zaire
74 Zambia
75 Zimbabwe
76 .#66 or Sudan or Swaziland or Tanzania or Togo or Tunisia or Uganda or Zaire or Zambia or Zimbabwe
77 .#76 in De

Asia.his

1 Afghanistan
2 Bahrain
3 Bangladesh
4 Bengal
5 Bhutan
6 Brunei
7 Cambodia
8 Cambodian
9 China
10 Chinese
11 Cyprus
12 Cypria
13 Timor
14 Gaza
15 Hong Kong
16 India
17 Indian
18 .#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #16 or #17
19 Indonesia
20 Indonesie
21 Indonesian
22 Iran
23 Iranian
24 Iraq
25 Iraqi
26 Israel
27 Israeli
28 Japan
29 Japanese
30 Jordan
31 Jordania
32 Korea
33 Korean
34 Kuwait

35 Laos
36 Lao
37 Lebanon
38 Macao
39 Malaysia
40 Malaysian
41 Malay
42 .#18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39 or #40 or #41
43 Maldives
44 Mongolia
45 Myanmar
46 Birma
47 Burma
48 Nepal
49 Nepalese
50 Oman
51 Pakistan
52 Pakistani
53 Philippines
54 Qatar
55 Saudi-Arabia
56 Singapore
57 Sri Lanka
58 Ceylon
59 Syria
60 Taiwan
61 Thailand
62 Turkey
63 United-Arab-Emirates
64 Viet Nam
65 Viet-Nam
66 Vietnam
67 Vietnamese
68 Yemen
69 .#42 or #43 or #44 or #45 or #46 or #47 or #48 or #49 or #50 or #51 or #52 or #53 or #54 or #55
70 .#69 or #56 or #57 or #58 or #59 or #60 or #61 or #62 or #63 or #64 or #65 or #66 or #67 or #68

Samerica.his

1 Silverplatterascii 3.0dosnasfa 1988-9/96
2 Argentina
3 Argentine
4 Bolivia
5 Bolivian
6 Brazil
7 Brazilian
8 Argentinian
9 Chile
10 Chili
11 Chilian
12 Colombia
13 Colombian
14 Ecuador
15 Guiana
16 Guyana
17 Paraguay
18 Peru
19 Peruvian
20 Surinam
21 Suriname
22 Uruguay
23 Venezuela
24 Venezuelan
25 .#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15
26 .#24 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23
27 .South-America
28 .#25 or #26

Oceania.his

1 Samoa
2 Australia
3 Australian
4 Christmas Island
5 Island*
6 Cocos Island*
7 Cook and #5
8 Fiji
9 French-Polynesia
10 Guam
11 Kiribati
12 Marshall and #5
13 Micronesia
14 Marianas
15 Nauru
16 New-Zealand
17 New-Caledonia
18 Niue
19 Norfolk and #5
20 Palau
21 Papua-New-Guinea
22 Papua-Neuguinea
23 Pitcairn
24 Samoa not American
25 Solomon and #5
26 Tokelau
27 Tonga
28 Tuvalu
29 Us Minor Islands
30 Vanuatu
31 Wallis Fut* Island*
32 .#1 or #2 or #3 or #4 or #6 or #7 or #8 or #9 or #10
33 .#32 or #11 or #12 or #13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #30 or #31

Stocking.his

1 Stocking
2 Release and Fingerlings
3 ((Releas* and Hatchling*) and (Fish in De)) not Turtles
4 Culture Based Fisher*
5 Pond-Culture
6 (#1 or #2 or #3 or #4) not #5

Namerica.his (Includes Central America and North America, where North America = Usa and Canada)

1 Anguilla
2 Antigua
3 Aruba
4 Bahamas
5 Bahama
6 Barbados
7 Belize
8 Bermuda
9 Bermudas
10 Canada
11 Canadian
12 Cayman
13 .#1 or #2 or #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12
14 Costa-Rica
15 Cuba
16 Cuban
17 Dominica
18 Dominican
19 El-Salvador
20 Greenland
21 Grenada
22 Guadeloupe
23 Guatemala
24 .#13 or #14 or #15 or #16 or #17 or #18 or #19 or #20 or #21 or #22 or #23
25 Haiti
26 Honduras
27 Jamaica
28 Martinique
29 Mexico
30 Mexican
31 Montserrat
32 Netherlands-Antilles
33 Antilles
34 Nicaragua
35 Nicaraguan
36 Nicaraguense
37 Panama
38 Puerto-Rico
39 Kitts-Nevis
40 Saint-Pierre-Et-Miquelon
41 Saint-Vincent
42 Trinidad
43 Turks-and-Caicos-I
44 Usa
45 Virgin-I-St-Croix
46 Virgin-Islands-Us
47 Virgin
48 .#24 or #25 or #26 or #27 or #28 or #29 or #30 or #31 or #32 or #33 or #34 or #35 or #36 or #37 or #38 or #39 or #40
49 .#48 or #41 or #42 or #43 or #44 or #45 or #46 or #47
50 .Central-America
51 .North-America
52 .#49 or #50 or #51
53 .#52 not Canada not Canadian not Usa

Fertili.his

1 Artificial Near Eutroph*
2 (Artificial Near Fert*) not Induced-Breeding not Pond-Culture
3 ("Habitat-Improvement-Fertilization" in De) not Pond-Culture
4 .#1 or #2 or #3
5 Manure not (Pond-Culture in De)
6 Reservoir
7 Lake
8 Water Body
9 Impoundment
10 Floodplain
11 .#6 or #7 or #8 or #9 or #10
12 .#5 and #11
13 .#4 or #12

Eng.his

1 Spawning Habitat
2 Breeding Ground*
3 Weed Cutting
4 Spawning Substrates
5 Spawning Gravels
6 Spawning Nest*
7 .#1 or #2 or #3 or #4 or #5 or #6
8 Engineering
9 Environment*
10 .#8 Near #9
11 Reserve*
12 Sanctuar*
13 Shelter
14 Aquatic Vegetation
15 Flood Control
16 Sluice*
17 Brush Park*
18 Artificial Reef*
19 Khata
20 Khua
21 .#11 or #12 or #13
22 Fish
23 .#21 Near Fish
24 Artificial Near Vegetation
25 Fish*
26 (#15 or #16) and Fish*
27 Enhancement*
28 Enhancement* Near #25
29 .#10 and #25
30 .#7 or #17 or #18 or #23 or #24 or #26 or #29

Introd.his

1 Species Transfer*
2 Species Introdu*
3 Exotic Species or Exotics
4 (Transplantings and Species) or (Transplantings and Fish)
5 (Colonization and Fish) not Plant* not Reef
6 .#1 or #2 or #3 or #4 or #5

ANNEX 2: METHOD FOR TRANSFER OF DOWNLOADED REFERENCES INTO MS EXCEL SPREADSHEETS

Filename: dbase.xls

1. make search profile for each enhancement option and region and save as follows:
    - name: enh$&.his
    - where: $=af (africa); sa (south america); na (north america); as (); eu (); oc ();
    - &=st (stocking); in (introd.); af (art.fauna); es (elimination sp.); fe (fert.); ee (eng.env.); gi (genetic impr.); mo (mod. WB) and ge (general)
    - example: enhafst.his
2. after primary selection and tagging download the tagged records as follows:
    - enh$&*.txt for import into excel. The file should include the fields TI,AU,SO,LA, AB, DE,AN, no field names, no search profile but record numbers yes (specify in the download options of WINSPIRS).
3. Copy the downloaded txt file into the excel spreadsheet
4. Check the following:
    - Adjust the number of iterations according to the numberof records in sheet 2 by editing macro1 in module1
    - The following fields have to be included in the download file from ASFA:
    - TI,AU,SO,PY,LA,AB DE,AN
    - Before starting the macro, check if the number of fields for each record is equal to 8, and if not insert rows
    - Check with Ctrl-d (macro 12)
    - place cursor at a2 in sheet 3 and A1 in sheet 2
5. Start macro ctrl-S from A1 in this sheet

Macro listings:

```
Macro1 Macro
' Macro recorded 10/4/97 by FAO
'
Sub Macro1()
   Do While counter < 30

   counter = counter + 1
   Call Macro11
   Loop
End Sub
Macro11 Macro
' Macro recorded 10/4/97 by FAO
'
Sub Macro11()
   Sheets("Sheet2").Select
   ActiveCell.Offset(1, 0).Range("A1").Select
   Selection.Copy
   Sheets("Sheet3").Select
   ActiveSheet.Paste
   Application.CutCopyMode = False
   ActiveCell.Offset(0, 1).Range("A1").Select
   Sheets("Sheet2").Select
   ActiveCell.Offset(1, 0).Range("A1").Select
```

```
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(0, 1).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(1, 0).Range("A1").Select
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(0, 1).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(1, 0).Range("A1").Select
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(0, 1).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(1, 0).Range("A1").Select
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(0, 1).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(1, 0).Range("A1").Select
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(0, 1).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(1, 0).Range("A1").Select
    Selection.Copy
    Sheets("Sheet3").Select
    ActiveSheet.Paste
    Application.CutCopyMode = False
    ActiveCell.Offset(1, -6).Range("A1").Select
    Sheets("Sheet2").Select
    ActiveCell.Offset(2, 0).Range("A1").Select
    Sheets("Sheet3").Select
End Sub
'
' Macro12 Macro
' Macro recorded 10/4/97 by FAO
''
Sub Macro12()
    ActiveCell.Offset(10, 0).Range("A1").Select
End Sub
```