FAO Fisheries Circular No. 1011 FIDI/C1011 (En)

ISSN 0429-9329

DEPLETED MARINE RESOURCES: AN APPROACH TO QUANTIFICATION BASED ON THE FAO CAPTURE DATABASE

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DEPLETED MARINE RESOURCES: AN APPROACH TO QUANTIFICATION BASED ON THE FAO CAPTURE DATABASE

by

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2004

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PREPARATION OF THIS CIRCULAR

This study is part of the continuing effort by the FAO Fishery Information, Data and Statistics Unit (FIDI) to promote use of the FAO fishery statistics through status and trends analyses. Following the “Chronicles of marine fishery landings (1950-1994): trend analysis and fisheries potential” by Grainger and Garcia (*FAO Fisheries Technical Paper* No. 359, 51p., 1996), which included several analyses of trends based on the revised and extended backwards time series of world capture fishery production, in recent years other studies on specific characteristics of marine species and of catch trends have been published.

A first study (Caddy and Garibaldi, 2000. “Apparent changes in the trophic composition of world marine harvests: the perspective from the FAO capture database”. *Ocean and Coastal Management*, No. 43 (8-9): 615-655) analysed catch trends on the basis of the trophic levels of the species caught. Another one (Garibaldi and Limongelli, 2003. “Trends in oceanic captures and clustering of large marine ecosystems: two studies based on the FAO capture database”. *FAO Fisheries Technical Paper* No. 435, 71p.) included two complementary studies: the former analysed the historical catch trends of oceanic species (epipelagic and deep waters) while the latter complemented the statistics on coastal species not considered in the oceanic section with additional information to re-arrange by Large Marine Ecosystems (LMEs) the data included in the FAO capture database by larger fishing areas.

The present study focuses on geographical stocks which have so drastically reduced their historical catches to be considered depleted in an attempt of quantifying the marine species in need to be restored as called for by the 2002 United Nations World Summit on Sustainable Development. In addition to these special studies, status and trends analyses based on FAO fishery statistics are published every two years in issues of the State of World Fisheries and Aquaculture.

ACKNOWLEDGEMENTS

The authors are greatly indebted to Mr Serge Garcia, Director, FAO Fishery Resources Division; Mr R. Grainger, Chief, FAO Fishery Information, Data and Statistics Unit; and Ms A. Crispoldi, Senior Fishery Statistician, FAO Fishery Information, Data and Statistics Unit, for their valuable comments on the manuscript.

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Garibaldi, L.; Caddy, J.F.
Depleted marine resources: an approach to quantification based on the FAO capture database.
FAO Fisheries Circular. No. 1011. Rome, FAO. 2004. 32p.

ABSTRACT

The 2002 United Nations World Summit on Sustainable Development called for species whose catches had been drastically depleted to be restored to health within 2015. An approach is proposed here to a preliminary classification, based solely on information included in the FAO capture database. Three criteria were used to filter catch data: the trend in recent years, the long-term trend, and the extent of decline in catches over the long term. These were applied sequentially to the data series for species items by fishing area recorded in the FAO capture database. About ten percent of the species items examined matched the selecting criteria. This is the same proportion of stocks classified as "depleted" by FAO based on assessment data although there are differences in the species identified. Reasons for these discrepancies are discussed.

The species groups with the highest percentages of species matching the three criteria were Gadiformes, molluscs (excluding cephalopods) and miscellaneous coastal and demersal fishes. Pelagic fishes (including Clupeoids) and crustaceans showed low percentages of depleted resources. Species considered depleted by this procedure are listed by FAO fishing area.

CONTENTS

1. INTRODUCTION

Eighteenth and nineteenth century thinkers such as Jean Baptiste de Lamarck and Thomas H. Huxley, assumed that the size of the oceans and the high fecundity of commercially exploited fish meant that marine fisheries resources were inexhaustible but, nowadays, serious stock declines are leading many scientists (e.g. Dulvy, 2004, Hilborn, 1997; Musick, 1999; Roberts and Hawkins 1999) to reconsider this former axiom. The 2002 issue of the FAO "State of World Fisheries and Aquaculture" (FAO, 2002a) expressed concern as to the status of global marine resources as follows: "*An estimated 25 percent of the major marine fish stocks or species groups for which information is available are underexploited or moderately exploited... about 47 percent of the main stocks or species groups are fully exploited... another 18 percent of stocks or species groups are reported as overexploited... the remaining 10 percent have become significantly depleted, or are recovering from depletion*". It went on to say: *"Recovery usually implies drastic and long-lasting reductions in fishing pressure and/or the adoption of other management measures to remove conditions that contributed to the stock's overexploitation and depletion."*

The urgent need to reverse stock declines was globally recognized by the United Nations World Summit on Sustainable Development (Johannesburg, South Africa, 26 August-4 September 2002). Its Plan of Implementation (Article 30) noted that despite progress with international fisheries agreements since UNCED, including the UN Fish Stock Agreement and FAO Code of Conduct for Responsible Fisheries, in order to achieve sustainable fisheries, it is necessary to: "*Maintain or restore stocks to levels that can produce the maximum sustainable yield with the aim of achieving these goals for depleted stocks on an urgent basis and where possible not later than 2015.*" (United Nations, 2002)

Following the depletion of some economically important fish resources, recovery plans have been set up by several fishing nations and regional fishery bodies. A global review (Caddy and Agnew, 2003ab) of stock recovery plans found 58 cases in which a recovery effort had been attempted with some degree of success. Most recovery efforts began after 1995 and recovery times were found to extend from between 4-8 years to 14-22 years or longer, depending on the periodicity of natural productivity variations as well as the biological characteristics of the species involved.

To assess stock status, an estimation of fishing and natural mortality rates, stock size and technical features of the fishery are needed and this work is carried out by experts, often in working groups, at the national level or in regional fishery bodies. in several fishing areas. However, in other fishing areas such arrangements are not yet in place and assessment data and expertise are often unavailable for many species possibly limiting awareness and corrective action. In these circumstances, it would seem desirable to see if an indicator of stock depletion can be derived from available catch data.

The main goal of this study is to identify the species which, in each FAO fishing area, would merit priority investigation as candidates for stock restoration measures, by measuring the extent and rate of decline, with respect to the maximum value of a 3-year running average of catches registered since 1970 in the FAO capture fishery production database. Three criteria were applied to the data series of species items by FAO fishing area. A match of all the criteria is considered an indicator that urgent attention is needed for this renewable resource on the part of fishery managers.

2. MATERIAL AND METHODS

2.1 Selection of relevant data series

At present, the FAO capture[1] database covers a 53 year-period (1950-2002), and includes data by country for 1 347 species items[2] (considering also freshwater species items), subdivided into 26 (19 marine and 7 inland waters) FAO major fishing areas for statistical purposes, containing more than 15 000 data series (FAO, 2004). Data can be downloaded[3] and consulted through the FISHSTAT+ software.

In selecting and managing data series for this study, the following rules were adopted:

a) species items reported from inland waters were excluded: only marine species were considered;
b) the analysis is restricted to the 1970-2002 period (33 years) since a component of catches before 1970 were estimated by FAO, either due to unavailability of data for some species/country, or because the species breakdown in early years was less detailed than is recently the case;
c) only data series where catch totals for the whole period exceed 100 000 tonnes (an average of over 3 000 tonnes per year) were considered;
d) catch data must be available for at least 20 continuous years and for the last five years of the series (1998-2002);
e) species items above the genus level were excluded;
f) if catches at the genus (e.g. *Trachurus* spp) and species level (e.g. *Trachurus trachurus*) are both recorded for a single fishing area, and if catches at the species level are less than 20% of the total catches for the genus, species catches were summed up within the data series for the genus.

2.2 Criteria established for the identification of depleted stocks

It would of course be ideal if criteria for depletion could be established from a formal stock assessment. Unfortunately, this is often not possible due to a lack of stock assessments, hence we have considered less rigorous criteria. The approach adopted was to filter the FAO capture database using criteria for stock depletion derived by FAO (2001). The objective was to establish an order of magnitude for the number of marine species in urgent need of recovery planning, and to find out, in a broad brush fashion, which resources in what area were most in need of restoration.

In quantifying species items in need of rebuilding by geographical area, the following criteria were applied:

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[1] Throughout this paper, the terms “catch” and “capture” refer to nominal catch and therefore exclude discards.
[2] "Species items" is the term used to identify the statistical taxonomic unit, which can correspond to species, genus, family or to higher taxonomic levels, but for ease of reading in the following, the species name alone may be used in place of “catches of a species item in a given FAO fishing area”.
[3] http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp

- ✓ *Criterion 1*: the slope of the catch trend over the last 5 years was negative;
- ✓ *Criterion 2*: the average rate of the catch decline between the peak period and the mean catches of last 3 years was greater than 5% per year;
- ✓ *Criterion 3*: mean catches of last 3 years had dropped below 20% of the peak value.

Peaks have been calculated as the median year on the basis of 3-year running averages over the 1970-2002 time period. The three criteria are illustrated in Figure 1 for a hypothetical time series.

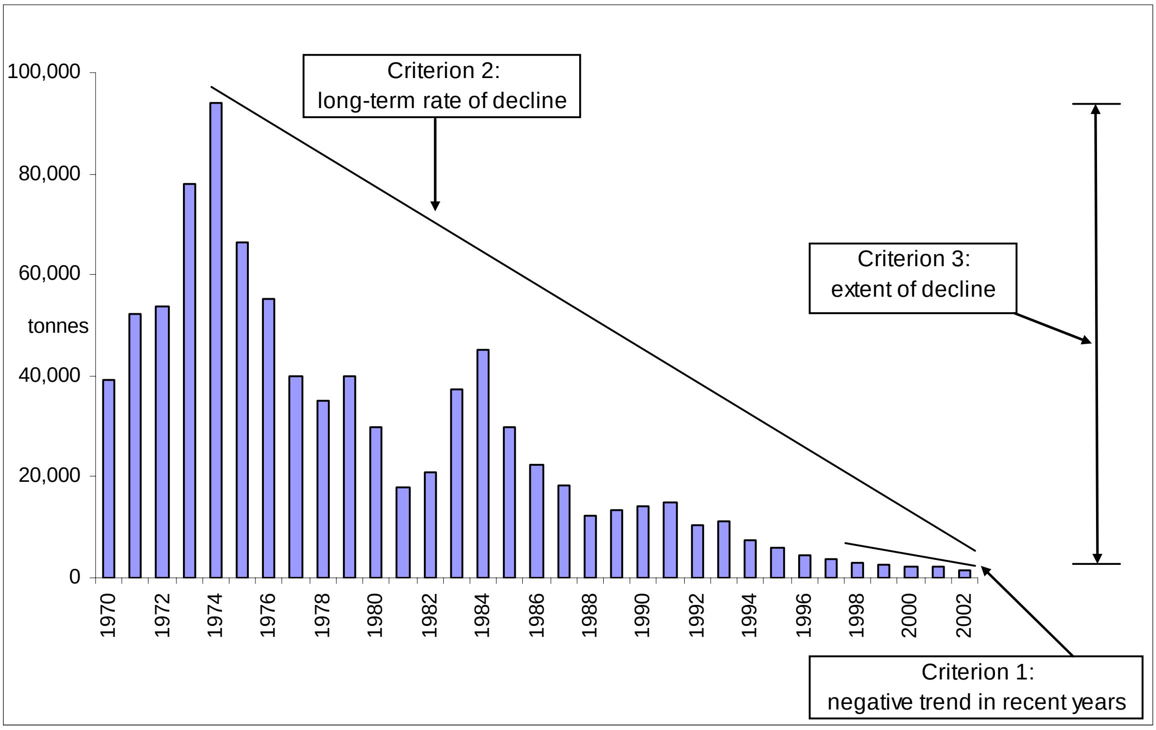

Figure 1. The three criteria applied to filtering a data series in the FAO capture database

Criterion 1 reflects the catch trend in recent years, and selects resources where catches have been actively declining, but excludes resources, though depleted, which have shown a recovering trend recently. Criteria 2 and 3 evaluate, respectively, long-term rate of decline and historical extent of decline from the catch peak, and these criteria are similar (though based on catches) to the proposed CITES listing criteria given in FAO (2001) which presume a knowledge of a time series of biomass which is rarely available. Although a cutoff point of 10% of the virgin stock size ($B_{0.1}$) is a fairly widely accepted Limit Reference Point, we used a drop in catches of 20% of the peak value, since a 10% cut off would have been over-restrictive given the other two criteria used.

2.3 Possible biases

Possible biases which may have partially interfered with the analysis performed could derive from flaws in the data series, a too coarse spatial resolution, and/or a short time scale in respect of changes in environmental regimes.

Although the FAO capture database is the most comprehensive and widely used source of information on global catch trends and efforts are constantly made to improve it, the authors are aware that some countries' submissions may not be fully reliable (FAO, 2002bc) and that catches are not always reported at the species level or species misidentifications may occur. Specifically, the main biases derived from flaws in the data series may be:

- Erroneous reporting: magnitudes of reported catches may be erroneous due to shortcomings in data collections and reporting systems; these will have most impact when the error levels change during the time period studied;
- Changes in reporting practices: improvements in national data collection and reporting systems during the period studied which now give a more detailed species breakdown, may conceal a decreasing trend.
- Incomplete identification: some catches of a species might have been included in a genus item or even in a higher taxonomic category.

As FAO fishing areas are large and may include several stocks of the same species, another source of bias may derive from considering all together the stocks in a given fishing area. As was recently the case of the small pelagic stocks off South Africa and Namibia, one stock could be declining while an adjacent stock of the same species may be in healthy condition (Anonymous, 2002; Barnard, 2002).

Many populations of marine fishes which are the target of fisheries show evidence of significant long-term fluctuations in abundance due to changes in the environmental conditions (Klyashtorin, 2001), also in the absence of fishing (Hilborn, 1997). As summarized by Spencer and Collie (1997), substantial variations occur over a range of time scales (from interannual to decadal and even centennial). The criteria used for this analysis and applied (in two cases) on time series 33-year long and, in one case, on the last five years, may be biased by environmental fluctuations which cover a term much longer than the time period considered, leading to confusion of natural decreases with depletion.

As a result of these biases, it is suggested that more detailed investigations at a local scale be carried out for species identified by this analysis as depleted in order to confirm otherwise the diagnosis.

3. RESULTS

3.1 Global trend

A total of 660 data series for species items by fishing area were selected from the FAO capture database according to the rules listed in section 2.1. Catches of these 660 species items made up three quarters (76.7%) of the total marine catches reported in the FAO database for the 1970-2002 period.

The three criteria described in section 2.2 were used to identify probable depleted species in the time series. Sixty-two species were found to match all three criteria, i.e. slightly less than 10% of the species items examined (Table 1). These species should be given priority for further investigation at the local level as potentially depleted stocks in urgent need of recovery.

Table 1. Number of species items matching the three criteria

	Examined no	**Matching criterion 1** no	**Matching criterion 2** no	**Matching criterion 3** no	**Matching all criteria** no	**Matching all criteria** %
Species items	660	350	292	102	62	9.4%

Criterion 1 (a negative slope over the last five available years) was matched by over half (53%) of the selected species. The high percentage (44%) of species items matching criterion 2 shows that almost half of the resources considered have declined at a rate averaging more than 5% per year since peak. Only about 15% of the resources examined met the third criterion (in that catches had dropped to below 20% of the peak value). However, it should be kept in mind that as the starting point of this analysis is 1970, the percentage of depleted stocks may be underestimated, as it could exclude resources which were heavily exploited before 1970.

The 62 species items represent 11.6% of total catches by the species examined over the whole 1970-2002 time period. In contrast, between 1983 and 1988, their share exceeded 20% of total catches, but by 2002, catches of those species which matched all three criteria were down to only 1.1% of the total catch of the 660 species items (Figure 2).

Trend and magnitude of total catches by depleted species were strongly influenced by the rise and fall of catches of the pilchards *Sardinops melanostictus* in the Northwest Pacific and *S. sagax* in the Southeast Pacific. These catch fluctuations have been extensively studied and mainly attributed to variations in environmental conditions (Kawasaki, 1992, 1993; Klyashtorin, 2001; Lluch-Belda *et al.*, 1989, 1992; Schwartzlose *et al.*, 1999). The catch trend of the other 60 species items combined has shown a continuous decline since 1974, in contrast to the abrupt drop in catches for the two pilchard species (Figure 3; see also Grainger and Garcia, 1996, for a similar figure and its description covering the 1950-1994 period).

Half of the species items which matched all three criteria had reached their maximum catch (calculated as the median year on the basis of 3-year running averages) in the first five years (1971-75) of the data series analysed in this study (Figure 4).

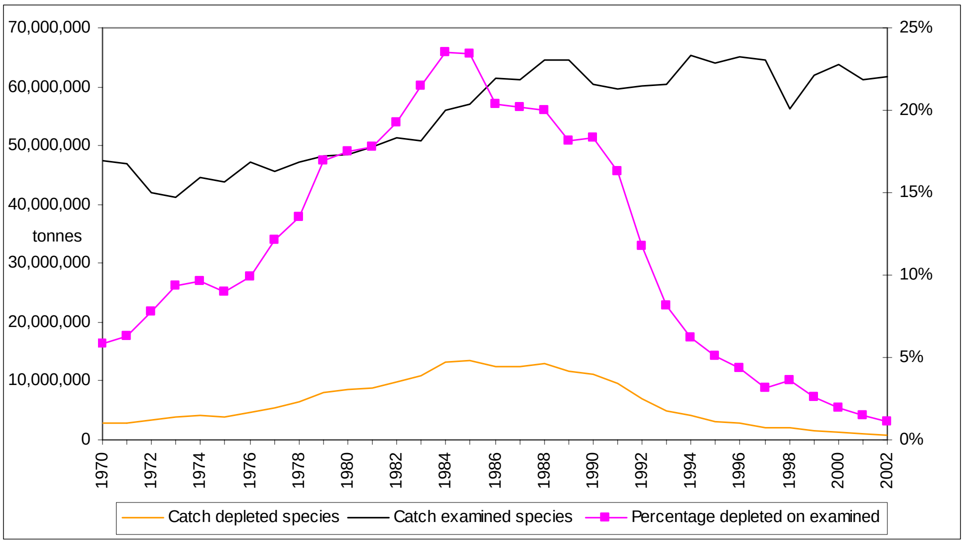

Figure 2. Catch trends of examined and depleted species items

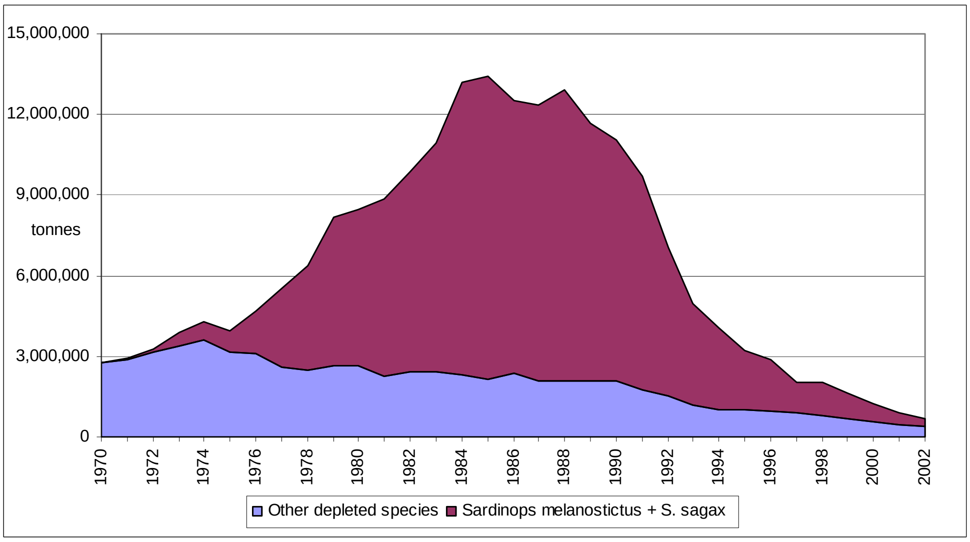

Figure 3. Catches of depleted species comparing Sardinops melanostictus+S. sagax *and other species grouped together*

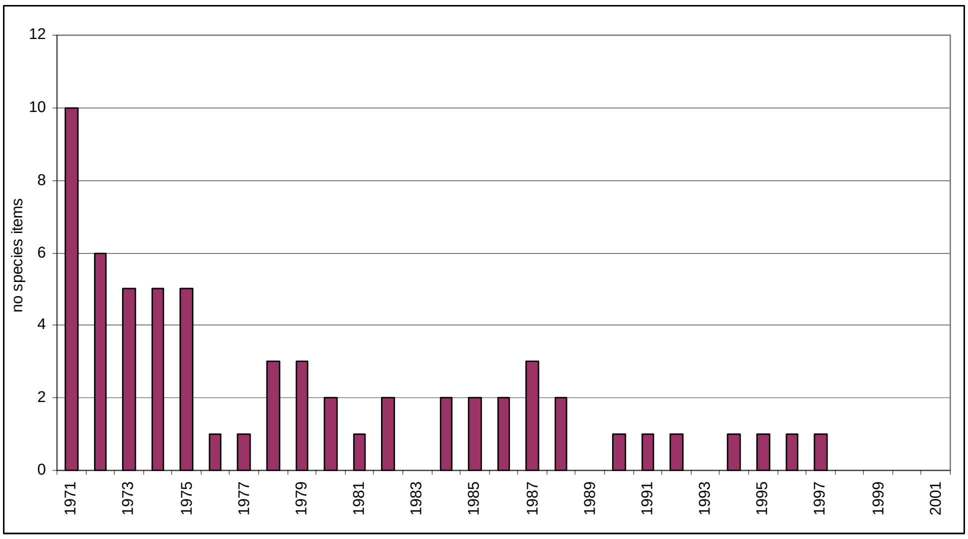

Figure 4. Year of maximum catch for the 62 depleted species items

Table 2 summarizes the numbers of species examined, those matching the three criteria, and the year of maximum catch in each marine FAO fishing area (see global map in Figure 5). Detailed lists of depleted species by fishing area are provided in section 3.2. The Northwest Atlantic is the area with the greatest percentage of species in need of recovery, with almost a quarter of items examined matching all three criteria. Other fishing areas showing high percentages of depleted stocks are the North and South Pacific in temperate waters, the Eastern Central Atlantic and Eastern Central Pacific in tropical waters, and the Antarctic areas, although for the Antarctic, adequate data were available for only a few species. The Mediterranean and Black Sea, and the Western Central Atlantic scored the lowest percentages of apparently depleted species, and no species items from the Eastern Indian Ocean and the Western Central Pacific matched all three criteria.

Table 2. Species items matching the three criteria by FAO fishing area

Fishing area code	**Fishing area name**	**Species items examined** no	**Matching all criteria** no	**Matching all criteria** %	**Year of maximum catch**
21	Atlantic, Northwest	43	10	23.3%	1973*
27	Atlantic, Northeast	73	7	9.6%	1976
31	Atlantic, Western Central	33	1	3.0%	1984
34	Atlantic, Eastern Central	44	6	13.6%	1990
37	Mediterranean and Black Sea	42	1	2.4%	1988
41	Atlantic, Southwest	37	3	8.1%	1997
47	Atlantic, Southwest	25	2	8.0%	1978
51	Indian Ocean, Western	36	3	8.3%	2002
57	Indian Ocean, Eastern	55	0	-	2002
61	Pacific, Northwest	96	12	12.5%	1998
67	Pacific, Northeast	25	3	12.0%	1987
71	Pacific, Western Central	58	0	-	2002
77	Pacific, Eastern Central	23	4	17.4%	2002
81	Pacific, Southwest	26	5	19.2%	1992
87	Pacific, Southeast	38	4	10.5%	1994
48-58-88	Antarctic areas	6	1	16.7%	1982
	TOTAL	660	62	9.4%	

*Maximum catch in the Northwest Atlantic occurred in 1968 but this year is prior to the period considered in this study.

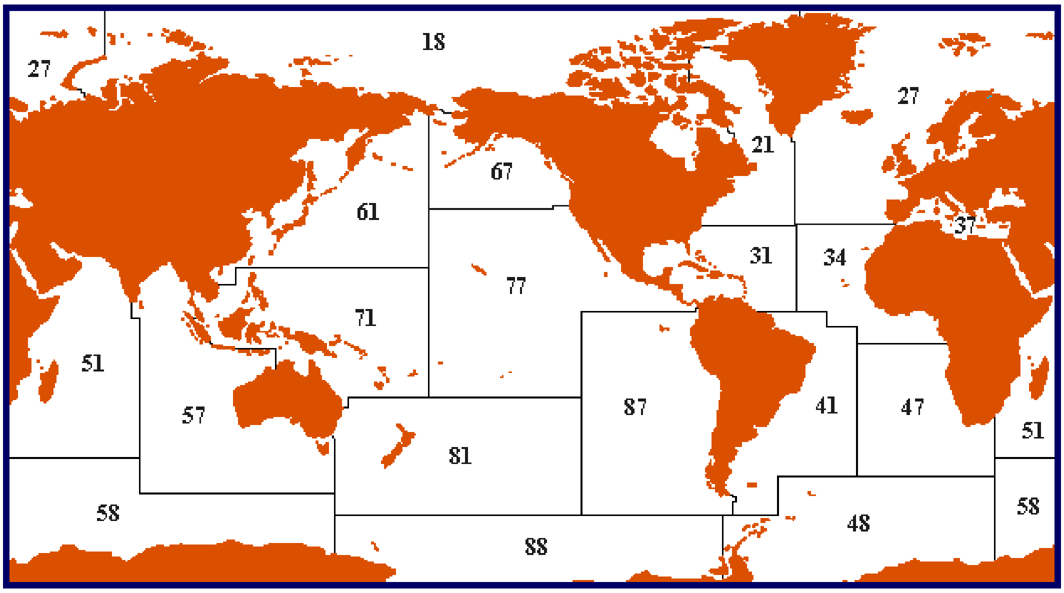

Figure 5. FAO major marine fishing areas for statistical purposes

In Figure 6, the percentage of species items (amongst the species analysed) matching all three criteria is plotted against the year of maximum catch for each fishing area. The trendline (although significant only for P=0.1) allows to note that some fishing areas which reached the maximum catch in relatively recent years, i.e. 34-Eastern Central Atlantic (1990), 81-Southwest Pacific (1992), 61-Northwest Pacific (1998), and 77-Eastern Central Pacific (2002), have a high percentage of depleted species in relation to their year of maximum catch, while areas like 27-Northeast Atlantic and 47-Southeast Atlantic, although they reached their maximum catch in the mid-1970s, show lower percentages of species matching all three criteria.

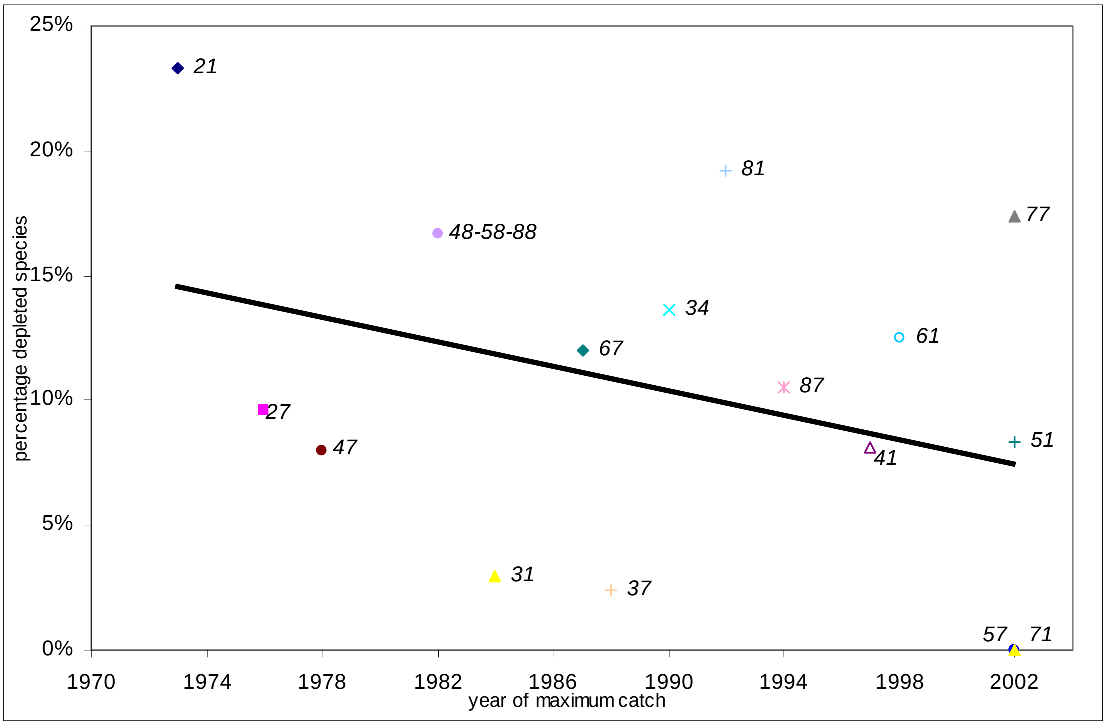

Figure 6. Percentage of depleted species plotted against the year of maximum catch by fishing area

To allow a comparison between species categories matching all three criteria, twelve groupings were set up based on the International Standard Statistical Classification of Aquatic Animals and Plants (ISSCAAP). The highest percentages of species matching all three criteria (see Table 3) were the Gadiformes (group 32), molluscs (excluding cephalopods), and miscellaneous coastal and demersal fishes. The Gadiformes, as a group, peaked in 1987 and since then, total catches of this group have dropped by almost 40% over fifteen years. Pelagic fishes (including the Clupeoids in group 35) and crustaceans, showed low percentages of depleted resources. No flatfish species matched all three criteria although their catches reached the maximum in 1971. Differences in percentages of depleted stocks between groundfish and small pelagics are high, and Gadiformes showed the fewest recoveries within the species groups studied by Hilborn (1997). Clupeoids, according to Hutchings (2000), are more likely recover after a collapse or depletion. Few sharks, species could be selected because the breakdown in statistics for this group has improved only in recent years. In the past, most catches of "sharks" were lumped under the generic item "Elasmobranchii". Thus, the real number of stocks in this group in need of restoration is most probably underestimated.

Table 3. Species items matching the three criteria by species group

ISSCAAP codes	Group name	Species items examined no	Matching all criteria no	Matching all criteria %	Year of maximum catch
22-25	Diadromous fishes	24	2	8.7%	1995
31	Flounders, halibuts, soles	31	0	-	1971
32	Cods, hakes, haddocks	46	7	15.2%	1987
33	Miscellaneous coastal fishes	106	12	11.3%	1997
34	Miscellaneous demersal fishes	52	6	11.5%	2000
35	Herrings, sardines, anchovies	60	5	8.3%	1994
36	Tunas, bonitos, billfishes	100	9	9.0%	2002
37	Miscellaneous pelagic fishes	86	7	8.1%	1996
38	Sharks, rays, chimaeras	10	1	10.0%	2000
42-47	Crustaceans	69	4	5.8%	2000
52-56, 74-77	Molluscs and other invertebrates	56	7	12.5%	2000
57	Squids, cuttlefishes, octopuses	20	2	10.0%	2000
	TOTAL	660	62	9.4%	1995

3.2 Lists of species items matching all three criteria by FAO fishing area

Species items which matched the three criteria are listed in tables for each FAO fishing area and a brief commentary is provided, mostly on catch trends and on available information suggesting the main causes of depletion, together with a chart of significant trends. These sections should definitely not be regarded as presenting a complete picture of the status of depleted species in each fishing area, due to the limitations imposed by an analysis of catch data alone and possible biases already described in section 2.3. The maximum catch and the year in which it occurred are those calculated on the basis of 3-year running average. The average of the last three years refers to the 2000-2002 catches.

3.2.1 Northwest Atlantic (FAO Area 21)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Alosa pseudoharengus	Alewife	22-25 - Diadromous fishes	1971	39 692	4 968
Brosme brosme	Tusk(=Cusk)	32 - Cods, hakes, haddocks	1981	7 573	1 467
Gadus morhua	Atlantic cod	32 - Cods, hakes, haddocks	1971	1 086 206	59 512
Merluccius bilinearis	Silver hake	32 - Cods, hakes, haddocks	1972	301 335	27 683
Pollachius virens	Saithe(=Pollock)	32 - Cods, hakes, haddocks	1986	72 884	11 086
Anarhichas spp	Wolffishes(=Catfishes) nei	34 - Miscellaneous demersal fishes	1978	15 149	1 465
Argentina spp	Argentines	34 - Miscellaneous demersal fishes	1973	26 908	17
Mallotus villosus	Capelin	37 - Miscellaneous pelagic fishes	1975	340 108	18 233
Crassostrea virginica	American cupped oyster	52-56,74-77 - Molluscs and other invertebrates	1972	176 467	19 405
Illex illecebrosus	Northern shortfin squid	57 - Squids, cuttlefishes, octopuses	1978	124 179	5 490

In the Northwest Atlantic fishing area, which ranked first by percentage of depleted species, most of the ten species items that matched the three criteria were demersal fishes, four of them Gadiformes. The crisis of the cod fishery in this area became fully evident in the early 1990s, but catches had already significantly decreased in the 1980s compared with the 1970s (see Figure 7). Despite the institution of a prompt fishing moratorium in February 1994 and a decade of severe conservation measures, fisheries for three cod stocks were closed off eastern Canada in 2003 (Fisheries and Oceans Canada, 2003a) as stock assessments determined that they are still at historically low levels, though some stocks may have begun to show signs of recovery. On the southern Grand Banks of Newfoundland, cod bycatch in other fisheries has increased to a point where it is reported as impeding the recovery of the stock, which was estimated to be at an extremely low level (Healey *et al*., 2003). Any recoveries of cod stocks by 2002 were partial and largely confined to southern Canadian zones and to the NE waters of the United States, suggesting climatic effects are acting negatively at the limits of species ranges, as supposed for North sea cod (O'Brien *et al*., 2000).

However, reductions in predatory finfish biomass may have contributed to rises in catches of other valuable shellfish resources in the NW Atlantic, including lobsters, snow crabs and shrimp resources in Canadian waters, (see: "*Shellfish has replaced groundfish as the foundation of the Atlantic fishery*" - Fisheries and Oceans Canada, 2003b), and the total value of all landings is now worth much more, despite the effective closure of many groundfish fisheries.

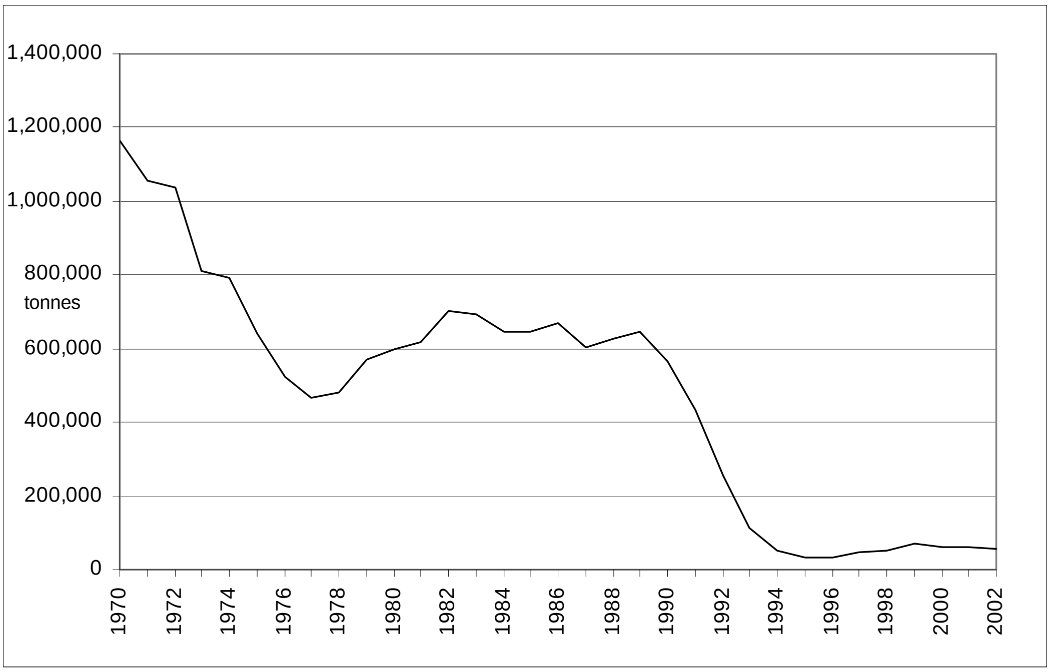

Figure 7. Catch trend of Gadus morhua *in the Northwest Atlantic*

3.2.2 Northeast Atlantic (FAO Area 27)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Merlangius merlangus	Whiting	32 - Cods, hakes, haddocks	1975	254 120	49 607

Trisopterus esmarkii	Norway pout	32 - Cods, hakes, haddocks	1975	738 805	135 058
Pagellus bogaraveo	Blackspot(=red) seabream	33 - Miscellaneous coastal fishes	1973	12 385	1 553
Zoarces viviparus	Eelpout	33 - Miscellaneous coastal fishes	1974	15 039	36
Lepidopus caudatus	Silver scabbardfish	34 - Miscellaneous demersal fishes	1972	5 567	812
*Katsuwonus pelamis**	Skipjack tuna	36 - Tunas, bonitos, billfishes	1988	9 221	1 604
Brama brama	Atlantic pomfret	37 - Miscellaneous pelagic fishes	1980	6 040	504

*See comment below

As for the Northwest Atlantic, in the Northeast Atlantic the two most important depleted species belong to the Gadiformes group. Catches of Norway pout (*Trisopterus esmarkii*) showed a series of ups and downs with progressively lower maxima, also interspersed by periodic signs of recovery (as in 2000). In contrast, the whiting (*Merlangius merlangus*) has shown an almost steady decreasing trend throughout its historical catch series (Figure 8).

Four other depleted species are mostly caught in oceanic waters; two of them (*Pagellus bogaraveo* and *Lepidopus caudatus*) being listed by the International Council for the Exploration of the Sea (ICES) among those deep-water resources that should be closely monitored and whose fisheries should be reduced unless they can be shown to be sustainable (ICES, 2002), while *Katsuwonus pelamis* (skipjack) and *Brama brama* (Atlantic pomfret) are offshore epipelagic species. However, the inclusion of skipjack as a depleted species in area 27 may be a flaw, due to the mismatch of statistical areas between FAO and the International Commission of the Conservation of Atlantic Tunas (ICCAT) from which “best scientific estimates” FAO derives most of the Atlantic tuna catches.

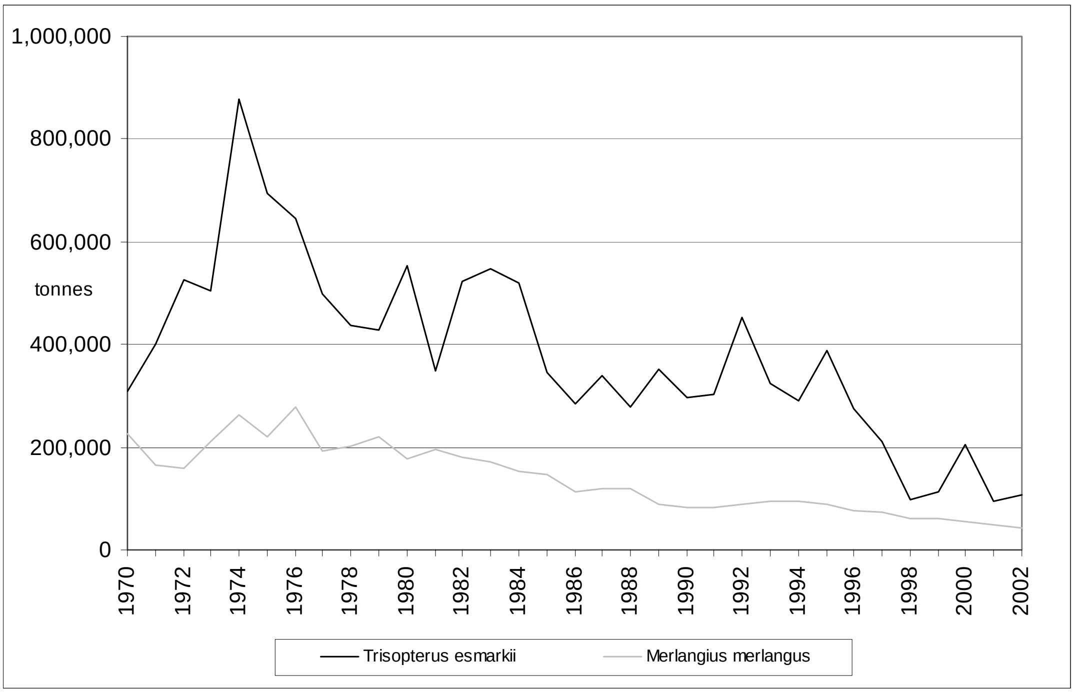

Figure 8. Catch trends of Trisopterus esmarkii *and* Merlangius merlangus *in the Northeast Atlantic*

3.2.3 Western Central Atlantic (FAO Area 31)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Micropogonias undulatus	Atlantic croaker	33 - Miscellaneous coastal fishes	1974	9 318	472

Only one species matched all three criteria in area 31; the Atlantic croaker *Micropogonias undulatus.* Catches for this species are reported by U.S. authorities in both areas 21 and 31, and their trends have markedly diverged since the mid-1990s (Figure 9). Direct fisheries in the Gulf of Mexico (area 31) have primarily harvested juvenile fish while in the Atlantic they targeted adult fish (Diamond *et al.*, 1999). Juveniles and young of *Micropogonias undulatus* also constitute 50% of bycatch by shrimp trawlers in the Gulf of Mexico (Chao, 2002).

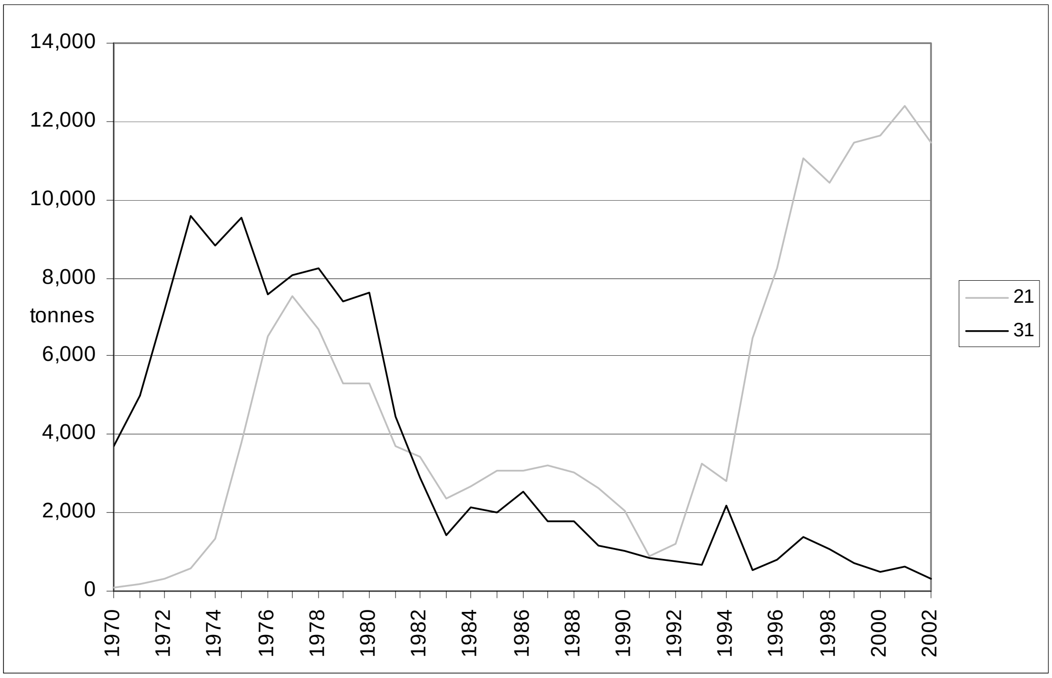

Figure 9. Catch trends of Micropogonias undulatus *in the Northwest (21) and Western Central Atlantic (31)*

3.2.4 Eastern Central Atlantic (FAO Area 34)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Merluccius senegalensis	Senegalese hake	32 - Cods, hakes, haddocks	1975	79 872	12 985
Dentex macrophthalmus	Large-eye dentex	33 - Miscellaneous coastal fishes	1974	39 672	1 467
Pagellus spp	Pandoras nei	33 - Miscellaneous coastal fishes	1971	17 851	1 946
Caranx hippos	Crevalle jack	37 - Miscellaneous pelagic fishes	1971	12 200	1 885
Caranx rhonchus	False scad	37 - Miscellaneous pelagic fishes	1991	15 948	1 987
Octopus vulgaris	Common octopus	57 - Squids, cuttlefishes, octopuses	1975	84 036	12 774

In recent years, declines of several populations of demersal resources in the Eastern Central Atlantic was pointed to by various studies. The 3rd Session (Lome, Togo, 24-26 February 2004) of the Scientific Sub-Committee of the Committee for the Eastern Central Atlantic (CECAF, 2004), reported that eighteen of the demersal stocks assessed were either fully exploited or overexploited, including *Merluccius senegalensis, Dentex macrophthalmus, Pagellus bellotti/*spp and *Octopus vulgaris* which are listed in the above table. The stock of the grouper *Epinephelus aeneus* was considered to be so overexploited that it was almost at risk of local extinction. This species and the "*Epinephelus* spp" species items were not examined in this study as they did not reach the minimum 100 000 tonnes of total catch for the whole 1970-2002 data series.

The two most important species which matched all three criteria, *Merluccius senegalensis* and *Octopus vulgaris,* showed a similar pattern of catch trends: strong fluctuations in the 1970s, slow declines in the 1980 and 1990s, and finally a significant catch drop in 2002 when their catches were down to less than 10% of the maxima reached in the 1970s (Figure 10). Instead, catches of *Dentex macrophthalmus* had already dropped by the end of the 1970s, and since then catches have always been low. Catches of Sparidae may have also been influenced by variations of demersal fish species assemblages that were reported to occur in the area between 1964 and 1990, and which provoked a decrease of species diversity between 1972 and 1982 (Koranteng and McGlade, 1998).

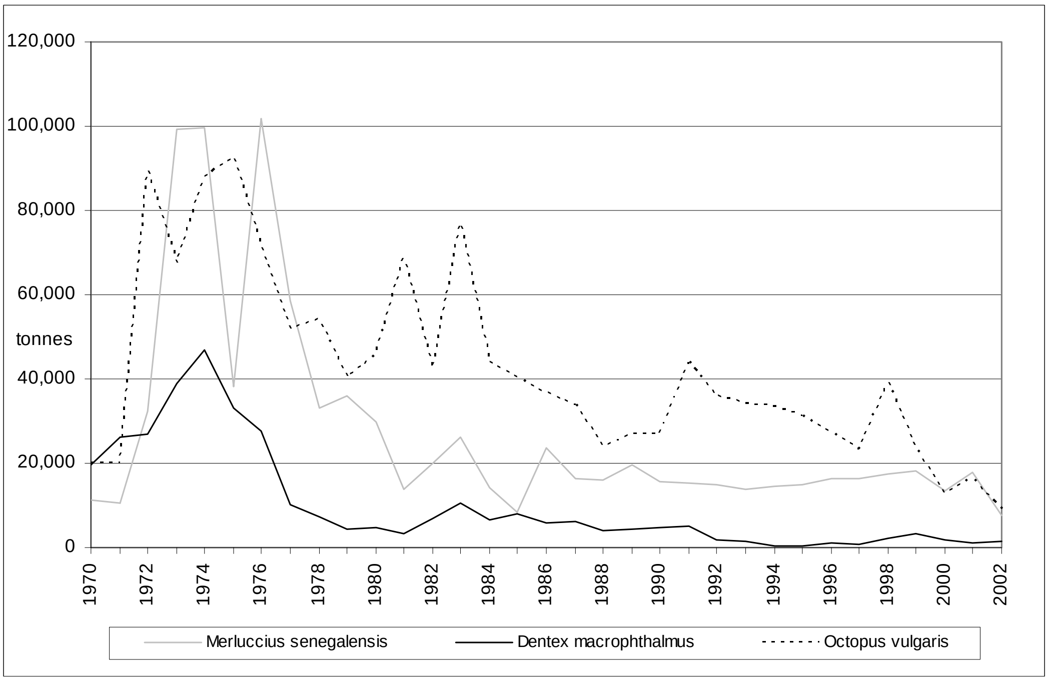

Figure 10. Catch trends of Merluccius senegalensis, Dentex macrophthalmus *and* Octopus vulgaris

3.2.5 Mediterranean and Black Sea (FAO Area 37)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Mustelus spp	Smooth-hounds nei	38-Sharks, rays, chimaeras	1984	12 809	2 537

Although levels of exploitation of several shared stocks in the Mediterranean should be reduced according to the 2004 meeting of the Stock Assessment Sub-Committee of the General Fisheries Commission for the Mediterranean (GFCM, 2004), no species target of fisheries were reported to be in critical status like in the Eastern Central Atlantic. The catch data for *Mustelus* spp (three valid species distributed in the Mediterranean) matched the three criteria as they dropped since the latest peak in 1994. As already mentioned in section 3.1, analysis of the catch series for sharks may be biased by the significant increase in recent years of the number of species items reported for this group, e.g. statistics for 20 Mediterranean shark species items reported in 2002 in comparison to 6 in 1970. However, the sharp catch decrease seems to be specific to *Mustelus* spp, as the trend for all other Elasmobranch species items together has not shown dramatic changes over the long-term (Figure 11).

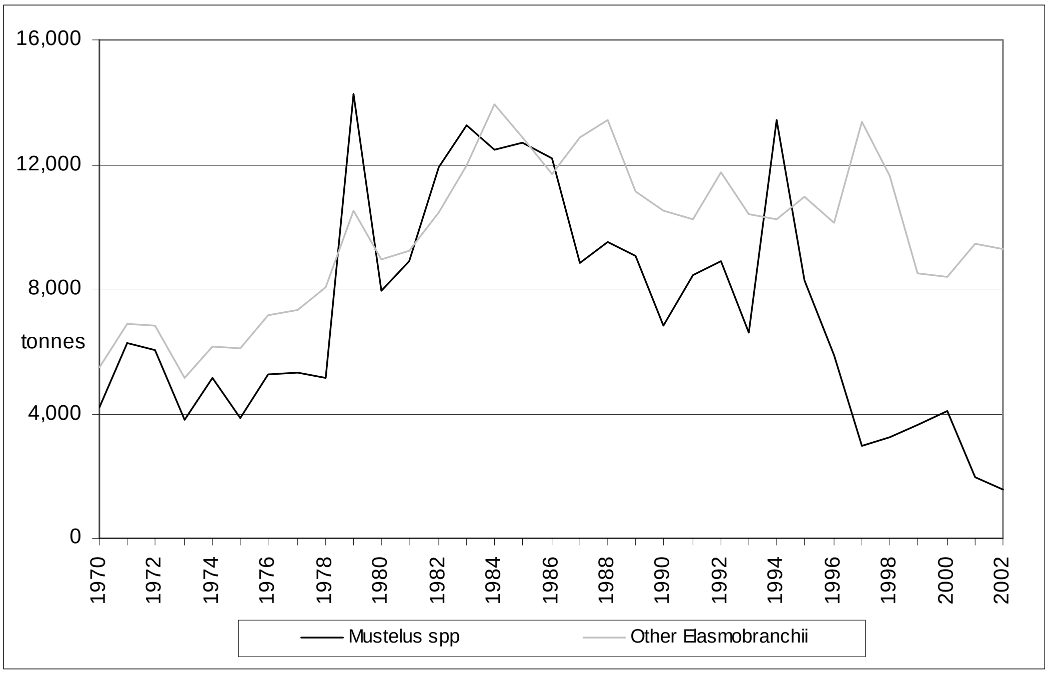

Figure 11. Catch trends of Mustelus *spp and other Elasmobranchii*

3.2.6 Southwest Atlantic (FAO Area 41)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Cheilodactylus bergi	Castaneta	34 - Miscellaneous demersal fishes	1995	13 752	1 099
Brevoortia aurea	Brazilian menhaden	35-Herrings, sardines, anchovies	1973	7 815	652
Sardinella brasiliensis	Brazilian sardinella	35-Herrings, sardines, anchovies	1973	191 930	27 994

The three depleted species in this area are very different in biological and ecological characteristics, in the type of fisheries targeting them, and hence the possible factors that may have influenced their decreasing catch trends (see Figure 12). *Cheilodactylus bergi* is a slow-growing species living on mud bottoms mostly at a depth between 50 and 150 meters (Cousseau and Perrotta, 2000). Up until the 1990s, it was mainly considered a bycatch of the hake fishery and commonly discarded (Norbis, 1989), but landings of over 10 000 tonnes were reported in 1970-73, 1994-95, and 1998, dropping to below 500 tonnes in 2002. The Brazilian menhaden *(Brevoortia aurea)* feeds on phyto- and zooplankton, spawns in estuaries, and is also caught as a bycatch in shrimp fisheries (Acha and Macchi, 2000; Radonic, 1997). It showed two isolated catch peaks in 1973 and 1995 but catches dropped sharply in recent years.

Up until 1990, the Brazilian sardinella *(Sardinella brasiliensis)* was the main Brazilian fishery resource by catch volume. Like others clupeoids, this species is strongly influenced by environmental factors, and a significant correlation has been demonstrated between environmental data and its catches (Sunye and Servain, 1998). The Brazilian fishery presented two critical periods (mid-1970s and late 1980s) associated with major changes in the regional climate and water conditions (Sunye, 1999). However, intensification of harvesting of young and pre-adults, and an increase in fishing effort may have contributed to the collapse to only 32 000 tonnes which occurred in 1990 (Valentini and Cardoso, 1991). After a recovery in the 1994-98 period, catches dropped again, and in the last three years averaged less than 28 000 tonnes.

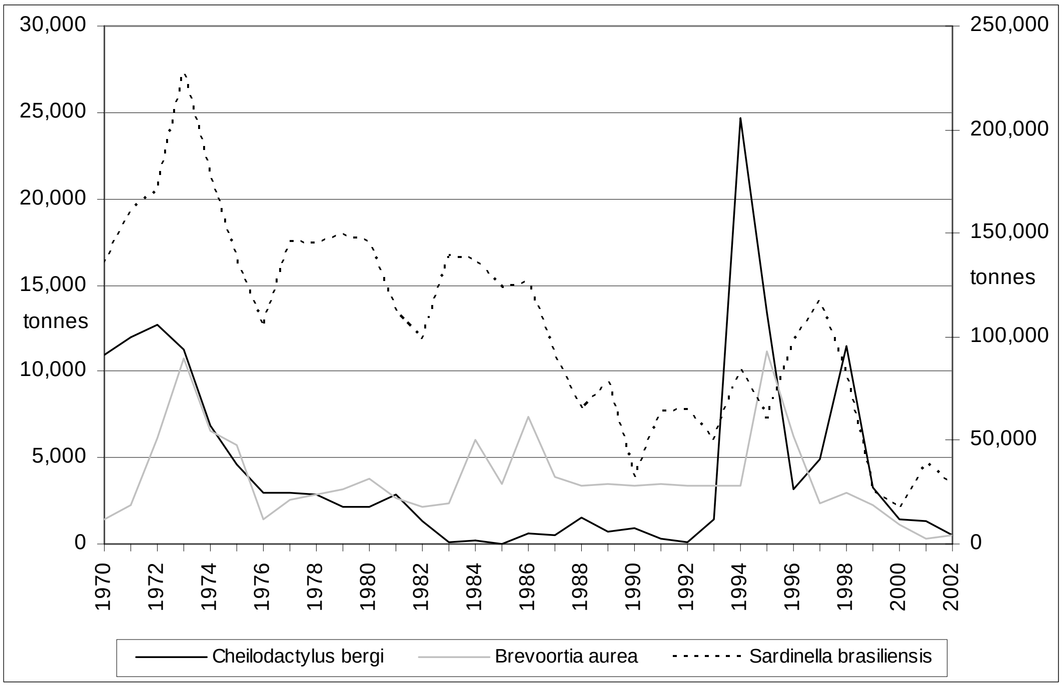

Figure 12. Catch trends of Cheilodactylus bergi *and* Brevoortia aurea *(values on the left axis), and of* Sardinella brasiliensis *(values on the right axis)*

3.2.7 Southeast Atlantic (FAO Area 47)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Dentex macrophthalmus	Large-eye dentex	33 - Miscellaneous coastal fishes	1977	33 678	1 272
Thunnus maccoyii	Southern bluefin tuna	36 - Tunas, bonitos, billfishes	1979	10 351	1 984

As found in the Eastern Central Atlantic, the data series for large-eye dentex (*Dentex macrophthalmus*) in the Southeast Atlantic matched all three criteria. The great majority (94 percent on average) of 1970-1987 catches were reported by the former USSR, but a sharp decrease had already occurred before the dissolution of the USSR and the 1990s reduction of its long-distance fishing activities. In 1987, catches of *Dentex macrophthalmus* had already dropped to one tenth of the 1976 maximum (43 192 tonnes).

The southern bluefin tuna, *Thunnus maccoyii,* is reported to be depleted by overfishing; thus by the mid-1980s, global stocks of this species had been fished down to approximately 10% of their 1960 biomass (Baldock, 2000). Despite a voluntary system of quotas which started in 1985 and was later (1994) formalized by the Convention for the Conservation of Southern Bluefin Tuna, parental biomass is still at very low levels (Cowling and O'Reilly, 2000). Southern bluefin tuna is mainly fished in the Indian Ocean (fishing areas 51 and 57), the Southeast Atlantic (47) and the Southwest Pacific (81), but minor and scattered catches were also reported from the Southwest Atlantic (41), the Western Central Pacific (71) and the Southeast Pacific (87). Catch trends for the first four areas are shown in Figure 13 (note that catches in area 57 also include production of tuna farmed by Australia since the early 1990s). Although catch decreases were evident in the other areas, only the data series in the Southeast Atlantic matched the three criteria, because in two fishing areas (51 and 81) the catch slope was positive over the last five years (criterion 1) and the data series for area 57 did not match criterion 3.

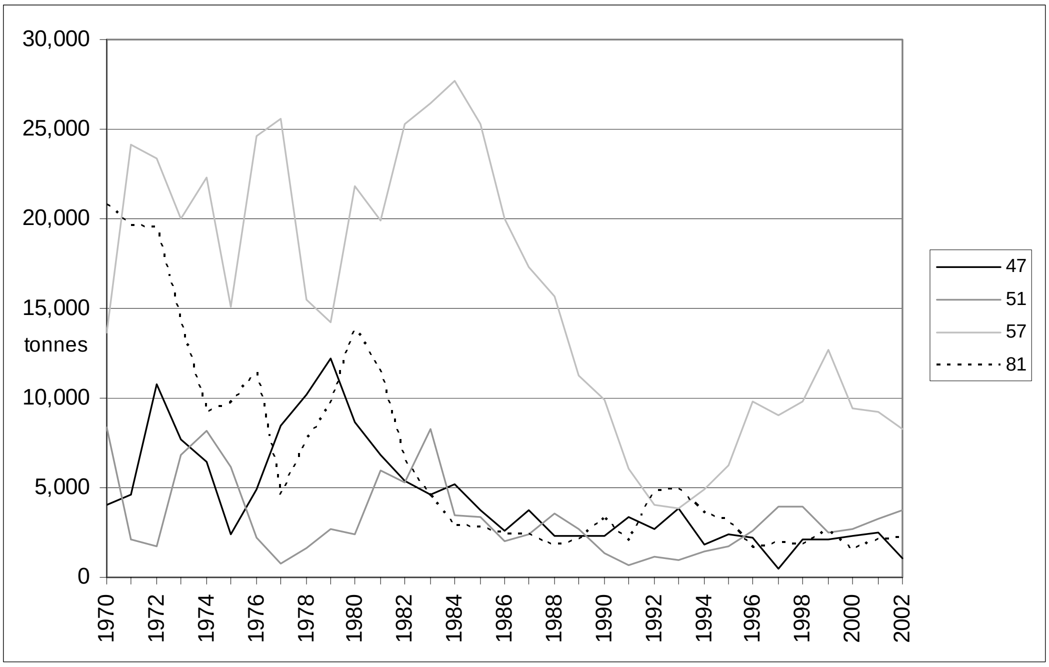

Figure 13. Catch trends of Thunnus maccoyii *in its four major fishing areas*

3.2.8 Western Indian Ocean (FAO Area 51)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Tenualosa ilisha	Hilsa shad	22-25 - Diadromous fishes	1971	11 833	620
Scomberomorus spp	Seerfishes nei	36 - Tunas, bonitos, billfishes	1979	16 335	3 203
Rastrelliger spp	Indian mackerels nei	37 - Miscellaneous pelagic fishes	1986	16 526	336

The Western Indian Ocean is one of four fishing areas in which total catches have still been increasing, and reached a maximum in 2002 (see Table 2). The data series for the three species items matching the three criteria (Table 11) may have been influenced to different degrees by some of the possible biases listed in section 2.3, due to inconsistencies in country reports.

The registered decrease in *Scomberomorus* spp catches is a result of the improved statistical species breakdown by India, which in 1981 began reporting catches by *Scomberomorus commerson* and *S. guttatus* instead of lumping them together under "*Scomberomorus* spp" as before. Catches of *Rastrelliger* spp were mostly reported by the former USSR up until 1987, and then for more four years by the Ukraine, but have dropped to minor quantities after these distant-water fleets ceased operations. Catches reported at the species level (*Rastrelliger kanagurta*) by coastal countries bordering the area, peaked in 1986 at 280 000 tonnes and decreased to 55 000 tonnes in 2002 (Figure 14).

The hilsa shad (*Tenualosa ilisha*), the most important of the Indo-Pacific shads, is distributed from the Persian Gulf eastward to Myanmar, and breeds mainly in rivers where there are permanent populations (Whitehead, 1985). Catches of this species have only been reported to FAO by Pakistan and Kuwait, although this species is also heavily fished in other countries (e.g. India). Catches reported by Pakistan have dropped from over 10 000 tonnes in the early 1970s to less than 1 000 tonnes in recent years. In India, human-induced modifications of the Ganges river basin destroyed the hilsa shad fisheries in the riverine stretch but also caused a significant catch increase in the Hooghly estuary area on account of the release of freshwater from the Farakka barrage (Sinha and Khan, 2001; Sinha *et al*. 1996).

Figure 14. Catch trends of Rastrelliger *spp (values on the left axis) and* R. kanagurta *(values on the right axis)*

3.2.9 Eastern Indian Ocean (FAO Area 57)

Also in the eastern part of the Indian Ocean, the maximum total catch was registered in the last year (2002) for which complete catch statistics are available, but differently from the Western Indian Ocean, none of the 55 species examined matched the three criteria.

3.2.10 Northwest Pacific (FAO Area 61)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Hypoptychus dybowskii	Korean sandlance	33 - Miscellaneous coastal fishes	1982	15 133	156
Priacanthus macracanthus	Red bigeye	33 - Miscellaneous coastal fishes	1972	19 600	3 069
Stephanolepis cirrhifer	Threadsail filefish	33 - Miscellaneous coastal fishes	1985	255 018	311
Takifugu vermicularis	Purple puffer	33 - Miscellaneous coastal fishes	1996	9 119	1 037
Upeneus spp	Goatfishes	33 - Miscellaneous coastal fishes	1971	8 779	754
Sebastes alutus	Pacific ocean perch	34 - Miscellaneous demersal fishes	1980	22 727	1 699
Sardinella zunasi	Japanese sardinella	35-Herrings, sardines, anchovies	1994	22 234	2 055
Sardinops melanostictus	Japanese pilchard	35-Herrings, sardines, anchovies	1987	5 313 674	293 915
Caranx spp	Jacks, crevalles nei	37 - Miscellaneous pelagic fishes	1987	37 276	4 763
Penaeus penicillatus	Redtail prawn	42-47 - Crustaceans	1984	8 370	376
Mytilus coruscus	Korean mussel	52-56,74-77 - Molluscs and other invertebrates	1976	13 690	1 055
Scapharca subcrenata	Half-crenated ark	52-56,74-77 - Molluscs and other invertebrates	1971	41 433	7 345

According to statistics reported, maximum catches in the Northwest Pacific were reached in 1998, although there are indications that capture fishery statistics by China have been overestimated, particularly in the 1990s (FAO, 2002c), and hence the catch peak may have occurred earlier. The high number of species items matching the criteria can be seen as a confirmation that several fish stocks have been overexploited in the Northwest Pacific (for a review of the status of Chinese marine resources, see Chen, 1999).

Almost all groups of species are represented among the 12 species items listed in the above table, but the most predominant category is that of coastal fishes with 5 species items. Catch statistics for these coastal fishes have been reported by coastal countries or areas in the region (China Hong Kong SAR, Korea Rep., Taiwan Prov. of China) but are not included in the species breakdown reported by China mainland. Catches of the overall coastal fishes group by China and other countries started to diverge significantly in mid-1990s, as can be clearly seen in Figure 15. The enormous reduction of *Sardinops melanostictus* catches has been already mentioned in section 3.1 as one the best known cases of catch fluctuation due to changes in the environmental regime, and its historical trend is shown in Figure 3.

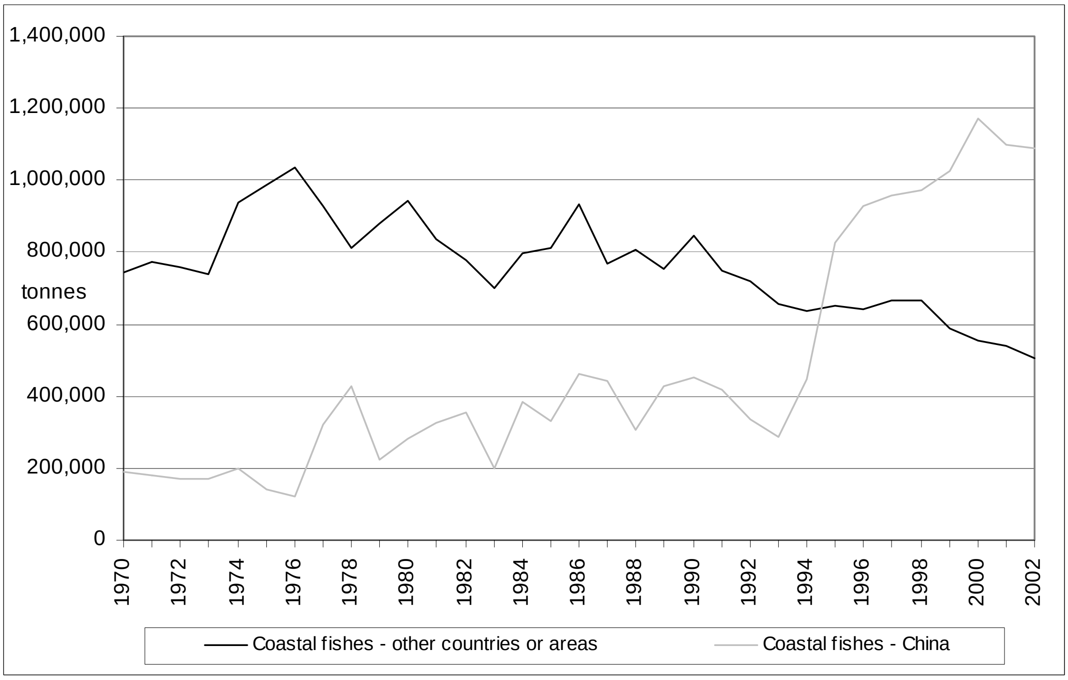

Figure 15. Catch trends of "Miscellaneous coastal fishes" in China and in other countries or areas of the region

3.2.11 Northeast Pacific (FAO Area 67)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Chionoecetes spp	Tanner crabs nei	42-47 - Crustaceans	1992	145 589	14 307
Paralithodes spp	King crabs	42-47 - Crustaceans	1979	71 132	7 248
Patinopecten caurinus	Weathervane scallop	52-56,74-77 - Molluscs and other invertebrates	1982	9 992	1 443

All three species items considered as possibly depleted in this area are invertebrates: a true crab, a king crab and a scallop. Crustaceans are very important fishery resources in the North Pacific, where in the PICES Region (which includes almost all of FAO statistical areas 61 and 67 and a small portion of area 77), provided 48% of 1998's world crab landings and 45% of world shrimp landings according to the data assembled by Otto and Jamieson, 2003. Catch trends for *Chionoecetes* spp and *Paralithodes* spp peaked in 1979-80, while for *Paralithodes* spp a sharp decline followed this maximum. Catches of *Chionoecetes* spp showed two other peaks in the early- and late-1990s (Figure 16). For both species items, average catches over the last three years have been at one tenth of the maximum catch.

A commercial dredge fishery for the weathervane scallop (*Patinopecten caurinus*) developed rapidly in the late 1960s, declined sharply in the mid-1970s due to local depletion (Kruse *et al*., 2000), and reached a peak in the early 1980s (according to catch data reported to FAO which, given their abrupt rise from previous levels, may be suspected to be influenced by improved reporting) and since then has shown a series of fluctuations averaging 3 000 tonnes per year. As well as mortality to the target species, dredging for scallops provokes habitat alteration by gear-induced damage and affects bycatch species such as *Chionoecetes* crabs, large quantities of which are incidentally caught in the scallop fisheries (Grant, 2000;

Rosenkraz, 2002). The weathervane scallop is cultured in British Columbia (Kingzett and Tillapaugh, 1999).

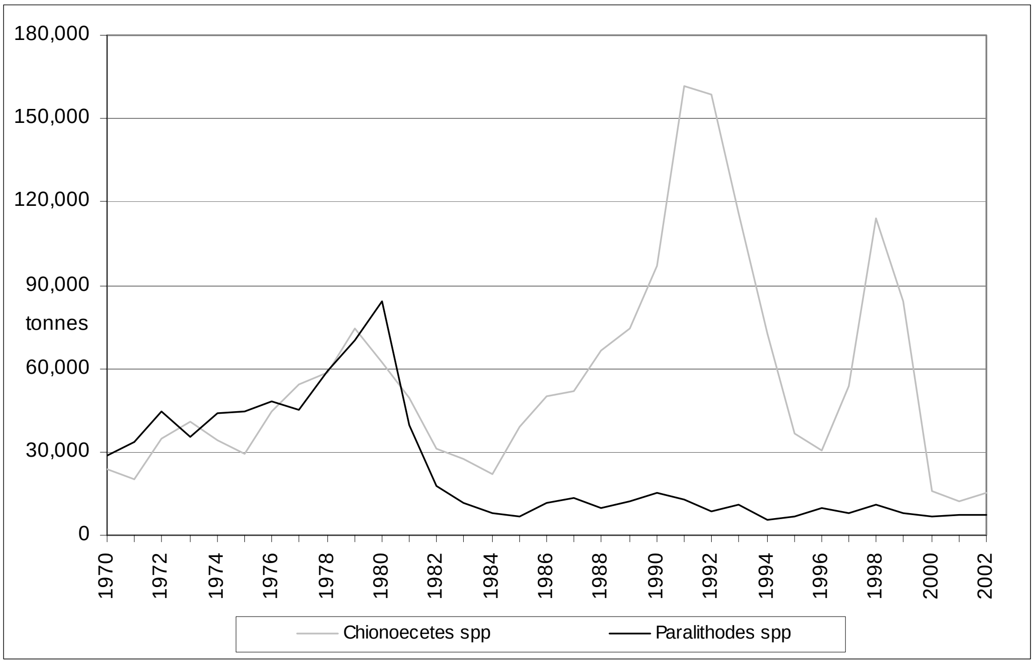

Figure 16. Catch trends of Chionoecetes *spp and* Paralithodes *spp*

3.2.12 Western Central Pacific (FAO Area 71)

Catch statistics for the Western Central Pacific presented the same positive picture as for the adjacent Eastern Indian Ocean area: catches are still growing and peaked in 2002, and despite the high number of species items examined (58), none matched all three criteria.

3.2.13 Eastern Central Pacific (FAO Area 77)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Sarda chiliensis	Eastern Pacific bonito	36 - Tunas, bonitos, billfishes	1974	13 909	303
Tetrapturus audax	Striped marlin	36 - Tunas, bonitos, billfishes	1971	9 967	1 265
Thunnus orientalis	Pacific bluefin tuna	36 - Tunas, bonitos, billfishes	1972	11 500	1 964
Haliotis spp	Abalones nei	52-56,74-77 - Molluscs and other invertebrates	1971	7 500	504

Three out of four species items matching the criteria in this area belong to the “Tunas, bonitos, billfishes“ group, the fourth is a mollusc. Catch histories of the three Scombroidei species are characterized by many ups and downs but with a general downward trend. Tunas and tuna-like species of the whole Eastern Pacific are managed by the Inter-American Tropical Tuna Commission (IATTC). According to its latest Fishery Status Report on tunas and billfishes in the Eastern Pacific Ocean (IATTC, 2003), although landings and fishing effort for striped marlin decreased in the Eastern Pacific from the early 1990s to recent years, the stocks of striped marlin stocks were apparently in good condition in 2002. For Pacific bluefin tuna, IATTC noted that its catches have been fluctuating over the last 50 years, and suggested that this may be due to consecutive years of above-average and below-average recruitment. The catch trend for Eastern Pacific bonito in area 77 is treated together with that of the southern population in the Southeast Pacific (area 87).

Mexico has been one of the major world producers of abalone for more than 50 years (Cesena, 1995) but catches declined first in the 1970s and then throughout all the 1990s (Figure 17). One of the species recorded under *Haliotis* spp, the white abalone *H. sorenseni*, was the first marine invertebrate proposed for the US endangered species list. The biological characteristics of this deep-living species make it particularly vulnerable to overexploitation (Hobday *et al.*, 2000). Mexico is developing abalone aquaculture to compensate decrease of capture fishery production.

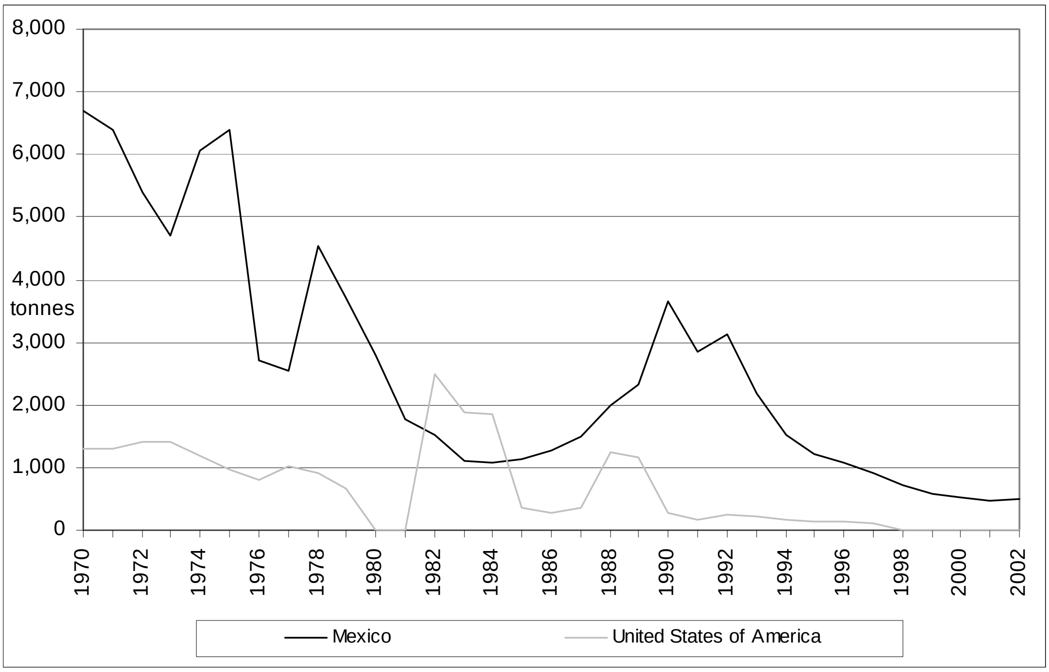

Figure 17. Catch trends of Haliotis *spp in Mexico and USA*

3.2.14 Southwest Pacific (FAO Area 81)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Rexea solandri	Silver gemfish	34 - Miscellaneous demersal fishes	1990	7 352	975
Thunnus albacares	Yellowfin tuna	36 - Tunas, bonitos, billfishes 6	1973	14 009	1 944
Thunnus obesus	Bigeye tuna	36 - Tunas, bonitos, billfishes 6	1974	12 579	2 291
Trachurus declivis	Greenback horse mackerel	37 - Miscellaneous pelagic fishes	1987	90 535	8 566
Ostrea lutaria	New Zealand dredge oyster	52-56,74-77 - Molluscs and other invertebrates	1978	9 811	805

Gemfish (*Rexea solandri*) is a mid-water species caught along the edge of the continental shelf of southern Australia and New Zealand. In the late 1970s and through the 1980s it made up a large proportion of demersal trawl catches off New South Wales (Rowling and Makin, 2001; see catch trend in Figure 18). Following declines in catch rate and mean fish size, a Total Allowable Catch (TAC) was imposed on the fishery despite significant opposition from the industry. In following years, it became apparent that the gemfish stock had been subject to a series of poor recruitments (Rowling, 1997). Recovery plans are encountering difficulties because the gemfish is caught as bycatch in other fisheries and increased protection of the species cannot be achieved unless a reduction in the overall catch of the fishery is implemented (Pascoe, 2000).

The New Zealand dredge oyster underwent a catastrophic reduction between 1985 and 1992 due to infestation by the protistan *Bonamia* spp (Doonan *et al*., 1994). Following a minor recovery in 1997, catches re-declined below 1 000 tonnes in recent years (Figure 18).

In the Southwest Pacific, the yellowfin and bigeye tunas were mostly caught during the 1970s by Asian DWFNs (i.e. Japan, Korea Rep., Taiwan Prov. of China). Their catches have dropped drastically since mid-1980s when coastal countries (Australia and New Zealand) also began to target these tunas. Also *Trachurus declivis* was mostly caught by DWFNs, in this case by the Soviet Union fleet, and following its dissolution, by those of the new independent republics which, however, significantly reduced their activities. No catches of this species by New Zealand are available from the FAO capture database as they are included under *Trachurus* spp, lumped together with those of *T. novaezelandiae*.

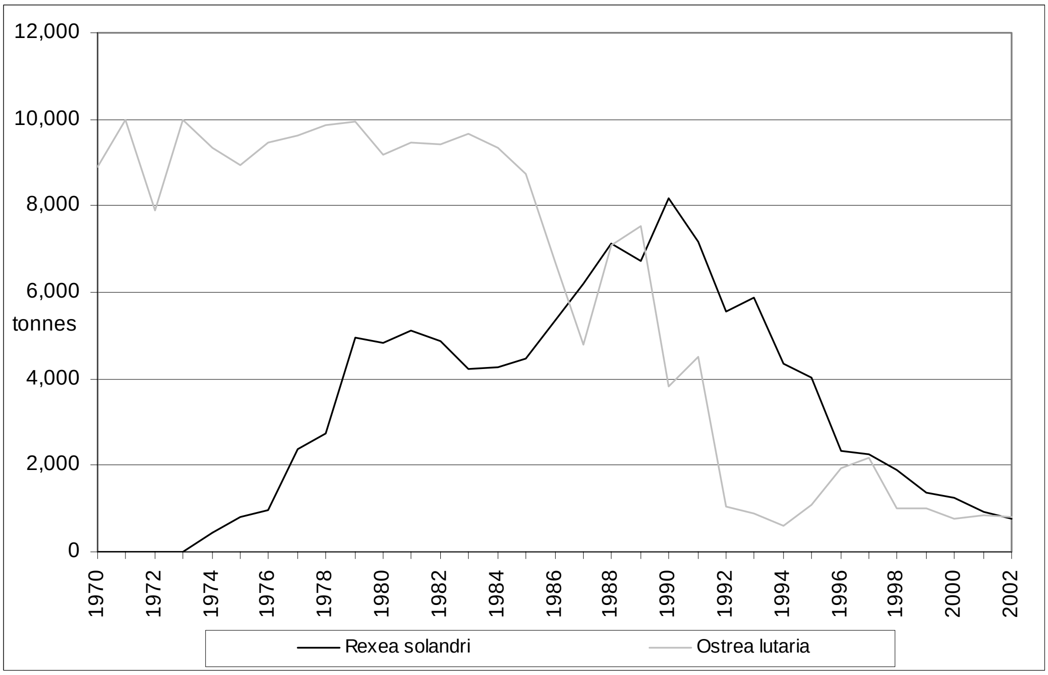

Figure 18. Catch trends of Rexea solandri *and* Ostrea lutaria

3.2.15 Southeast Pacific (FAO Area 87)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Sardinops sagax	South American pilchard	35-Herrings, sardines, anchovies	1985	5 734 913	167 265
Sarda chiliensis	Eastern Pacific bonito	36 - Tunas, bonitos, billfishes 6	1971	68 467	898

Penaeus spp	Penaeus shrimps nei	42-47 - Crustaceans	1997	14 546	2 046
Mesodesma donacium	Macha clam	52-56,74-77 - Molluscs and other invertebrates	1988	16 259	1 348

Sarda chiliensis has an antitropical distribution with two separate populations, one in the northeast Pacific from Alaska to Baja California, and the southern one from Peru to as far south as Concepción in Chile (Collette and Nauen, 1983). Catch data for both populations are reported separately for areas 77 and 87 and match the three criteria, but and are presented together in Figure 19.

Catches of both *Sardinops sagax* and *Sarda chiliensis* are influenced by environmental factors although they have shown asynchronous peaks. Klyashtorin (2001) classified 12 global major commercial species into two groups, on the basis of their long-term dynamics. *Sardinops sagax* was included in the first group among those species which maximum catch occurred in the late 1930s and early 1990s. *Sarda chiliensis* was not considered in the Klyashtorin's study, but probably can be assigned to the second group whose catches increased and decreased in opposite phase to the first group (Figure 19). A study over a shorter time period (Cubillas and Fuenzalida, 1990), found that *Sarda chiliensis* belonged to a group of species whose catches increased in northern Chile during the warm period in the eastern Pacific Ocean between 1976 and 1984, while in the same years, landings of other commercially important fishes were affected negatively.

Climatic oscillations in the area also influenced harvests of populations of the clam *Mesodesma donacium,* as growth, recruitment and mortality and, therefore, production varied during and after El Niño of 1982-1983 (Arntz *et al*., 1987). The catch trend of this species shows some similarities to that of *Sarda chiliensis* and this species seems a candidate to be included in Klyashtorin's second group. Shrimps are not very relevant in the area in terms of catches. For the whole group and for *Penaeus* species items, peaks occurred in 1983 and between 1991 and 1998, but halved over the last four years.

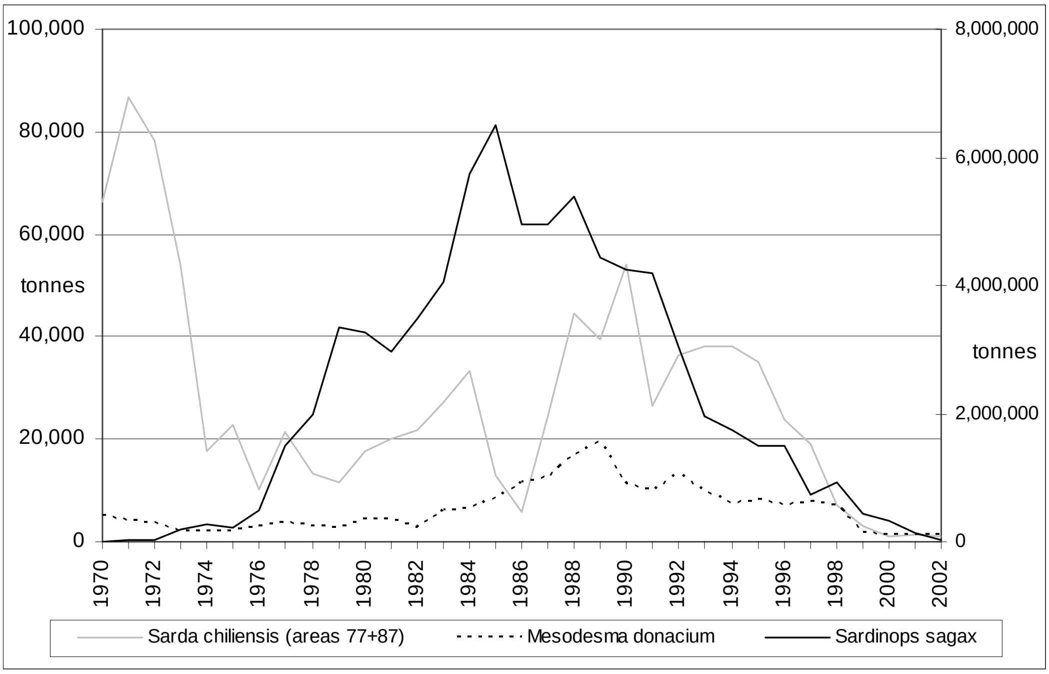

Figure 19. Catch trends of Sarda chiliensis *(areas 77+87) and* Mesodesma donacium *(values on the left axis), and of* Sardinops sagax *(values on the right axis)*

3.2.16 Antarctic areas (FAO Areas 48, 58, 88)

Scientific name	FAO English name	Species group	Year of maximum catch	Maximum catch	Last 3 years catch average
Notothenia squamifrons	Grey rockcod	33 - Miscellaneous coastal fishes	1972	26 608	0

As already mentioned in section 3.1 on "Global trends", only 6 out of 135 species items included in the FAO database for the three Antarctic areas (data almost completely derived by the CCAMLR database) could be examined, because only 11 data series had cumulative harvests of over 100 000 tonnes for the whole 1970-2002 period. Four of these did not have data for 20 continuous years, and one was recorded at above the genus level. Among the six species examined, only *Notothenia squamifrons* in area 58 (Antarctic, Indian Ocean) matched the three criteria. Its catch trend shows major peaks in early and late 1970s, like that of all fish catches in the Antarctic (Figure 20; the scale of fish catches other than *N. squamifrons* shown on the right axis). Possible recent depletions would have been masked by the huge catches taken before 1982, when the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) came into force.

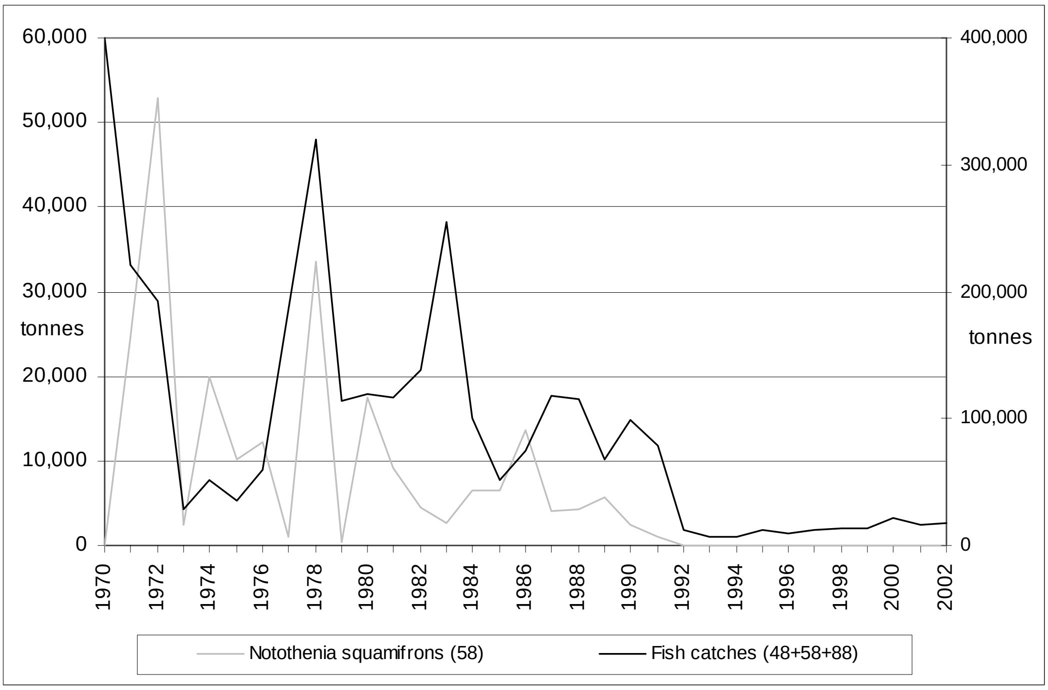

Figure 20. Catch trends of Notothenia squamifrons *in area 58 (values on the left axis) and of fish in the Antarctic areas (values on the right axis)*

3.3 Comparison with the species classified as depleted on the basis of stock assessment information

Although different methods and datasets have been used, the percentage (9.4%) of species items considered as depleted by this study based on FAO capture statistics matches the 10% of the main marine fish stocks classified as depleted, or recovering from depletion, on the basis of available assessment information (FAO, 2002a). This would support the general confidence expressed by Garcia and de Leiva Moreno (2003) that the global trends observed in landings reflect trends in the stocks monitored by FAO. However, a detailed comparison between the two lists[4] of species classified as depleted showed that only few species items were present in both lists.

The number of species items[5] evaluated on the basis of available stock assessment data was slightly over half of the species items examined in this analysis. About one third of the species classified as depleted by stock assessment data were not selected to be analyzed in this study (most cases are in the Mediterranean and Black Sea, Southeast Atlantic, and in Antarctic areas) as their total catches along the whole 1970-2002 period did not exceed the 100 000 tonnes limit (see section 2.1 “Data series selected”).

The Northwest Pacific (scarce availability of stock assessment data) and Northwest Atlantic (marked catch decreases since historical peaks) are the fishing areas in which the number of depleted species on the basis of catch statistics more largely exceeded that of species classified as depleted on the basis of stock assessment. In other areas (e.g. Eastern Central Atlantic and Southwest and Southeast Pacific), some of the stocks which matched the three criteria applied to the statistical data series were classified as “Overexploited” but not as “Depleted” in the tables based on stock assessment data.

For what regards species groups, the number of coastal fishes, sharks, and molluscs (excluding cephalopods) listed in the “State of exploitation” tables is quite low in comparison to the 172 species items of these groups examined in this analysis, 20 of which matched the three criteria. The scarce number of species items of these three groups presented in the tables is probably due to the lack of assessment data and for several areas they have been assessed at the family or at the group level. On the contrary, species belonging to Clupeoids, Gadiformes and diadromous fishes, for which more biological and fishery data are available, are well represented in the “State of exploitation” tables.

Besides the specific reasons already mentioned, some differences in the species identified as depleted by the two analyses are implied in the methods themselves. When filtering the catch data series by the three criteria to select depleted species, a considerable weight is given to the historical catch levels. This is proved by the fact that among the species classified as depleted using stock assessment data but which were not identified as such in the present analysis, the criterion which was not matched in most cases was the third one, i.e. recent catches should have dropped below 20% of the peak value. On the other hand, evaluation based on stock assessment methods takes into account, in addition to catch data,

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[4] For this purpose, it was used the latest version (updated to 2002 data and available internally in FAO but not yet published) of “State of exploitation” tables by FAO fishing area (criteria adopted described in FAO, 1997).

[5] For consistency with the rules established in this analysis, species items above the genus level were excluded. When more than one category was assigned to a stock, it was considered as classified in the worst category (e.g., a stock classified as “Overexploited – Depleted” was considered as “Depleted”).

also information on biological and fishery parameters which cannot be derived from the catch statistics.

In conclusion, stock assessment remains the mainstream method to identify species which may be considered as depleted but, notwithstanding the limitations and possible biases (mentioned in section 2.3) in using capture statistics, the method suggested by this study proved to provide complementary information and offer useful clues when stock assessment information is not available.

4. DISCUSSION

Without a full stock assessment, an evaluation based solely on catch time series can only be tentative. Nonetheless, most world fisheries are still not operating under management regulations which effectively restrict allowable catches. Given the increase in international trade in fish and fishery products, a sharp decline in landings is rarely due to a loss of commercial interest, but for some species may be our first indicator of the urgent need for fishery management. Where management control applies, a drop in catch quotas or permitted fishing effort to low levels is, in any case, an indication that the stock size has fallen significantly from earlier higher levels.

The information on the depleted species presented in the sections by fishing area only allows a broad review of the main factors causing stock depletions. A change in climatic conditions, sometimes associated with a concomitant high fishing pressure, seems to be involved in some major drops in catch magnitude (see Figure 3). Overfishing is the main depleting factor in several cases, in particular when the target species is highly sought after, and of high unit value (e.g. southern bluefin tuna). Stocks of at least four species were depleted not only because they were a target of fisheries, but since they were taken as bycatch in other fisheries. Bycatch of species already depleted (e.g. cod and gemfish) often impede the recovery of the stock unless a reduction in the overall fishery is imposed, which may be difficult to implement.

Human-induced alterations of the environment may lead to severe stock decreases, and can be caused by the fishery operations itself (e.g. modification to the sea floor by a dredge fishery) or by habitat modifications affecting one or more life stages of a species target of fishery. Excessive harvests of mainly juvenile fish (e.g. Atlantic croaker in the Gulf of Mexico) could be another factor altering the healthy status of a population. Massive mortality can be also induced by non-human factors, e.g. the infestation by a parasite of the New Zealand dredge oyster. Finally, as expected, several species among those classified as depleted have life history characteristics (e.g. living in deep waters, slow-growing, late maturing, low fecundity) which made them more vulnerable and less resilient to external pressures such as fisheries.

Can we meet the Johannesburg directive? The task called for in Johannesburg, namely to restore stocks to levels that can produce the maximum sustainable yield, would require actions affecting about ten percent (according to the result of this analysis) of major global marine fishery resources if only depleted stocks should be taken into consideration but this percentage would grow to about 30% if also stocks classified as overexploited (Garcia and de Leiva Moreno, 2003) should be restored. If only the second and third criteria on long-term rate and extent of decline would have been used, even though recent catches might have been stable or beginning to increase, we would have concluded that a high proportion of resources have been fished down to well below their potential based on historical catches, which also calls for management action over the medium-longer term. Stock rebuilding in the light of a changing environment will impose considerable challenges and inevitably a high cost, although the alternative of taking no action will in the long run be even more severe. Limited experience to date with rebuilding, and the relatively small number of successfully restored stocks listed in Caddy and Agnew (2003ab) adds to the challenge we face in implementing the Johannesburg directive within the 11 years remaining before 2015.

The following paragraphs are largely based on ICES papers which are not generally available (Caddy and Agnew, 2003ab). Based on the few recovery plans successfully implemented to date, these authors show that restoring demersal stocks is a much more difficult task than for pelagic fish and invertebrates, especially on high latitude fishing grounds. Caddy and Agnew found that groundfish plans have so far been successful in 12 (46%) of the cases located, while 8 (67%) plans or closures were partially successful for pelagic fish. Ten (71%) invertebrate "recoveries" were documented, with or without a specific plan, possibly in some cases due to reduced predation from recently collapsed groundfish stocks. These results for finfish are supported by Hutchings (2000), who by analysing 90 data sets for 38 species, concluded that herring-like fishes have a much higher potential for rapid recovery than groundfish: many small pelagics had recovered 5 years after the major decline. For groundfish however, even 15 years after the period of largest decline in the stock history was over, 40% of stocks continued to decline.

Longer-lived shelf gadoids such as cod have generation times of 8-10+ years, which implies that recovery times of at least a decade will be needed after the first good year class occurs following initiation of the plan, in order to restore one good age class. Since runs of poor recruitment often continue for at least 5 years, this requires a further precautionary period to be allowed for, making recovery times upwards of 15 years more realistic. Recovery times of as much as a half century may be needed to restore very long-lived resources such as sturgeons, and deep water species such as ocean perch in the North Pacific (MacCall, 2002) and orange roughy which live to half a century or more. Given the high growth rates and short life spans of many tropical fish and small pelagic fish, recovery times for these resources may be relatively short, a decade or less.

Rapid recovery may be also compromised if environments are unfavourable, or if stocks are reduced too much below 30% of the unexploited stock size which is generally considered a safer limit to exploitation, although recoveries from as low as 10% of the unfished stock have been documented under favourable regimes. Local recoveries of mainly tropical shallow shelf resources have been achieved relatively rapidly by closing local areas to fishing, but recoveries of high latitude demersal stocks will require longer periods, and will probably need to be supplemented by large closed areas and technical measures. Unfortunately, relatively few large scale area closures studied for and adopted to demersal fisheries have been attempted in temperate zones, although this mechanism seems to improve chances of success over a decadal time frame.

The socio-economic impacts of a major reduction in fishing effort or fishery closure over a significant period of time would have to be absorbed, and the high costs involved were evident from the longer-term impacts of cod collapse on Newfoundland fishing ports. It is reported (Fisheries and Oceans Canada, 2003a) that the closure of three cod stocks in eastern Canada involved a $50 million program to assist individuals and communities affected by the closure, in addition to the earlier government expenditures associated with the moratorium. This emphasizes the major scale of losses of income and employment resulting from fish stock collapses.

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