Rising to Depletion?
Towards a dialogue on the state of national marine fisheries

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Rising to Depletion?
Towards a dialogue on
the state of national marine fisheries

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prepared for

Global Program on Fisheries
(PROFISH)

by

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Above: The Rise to Depletion – evolution of a fishery sector
Below: Development of bottom fish fisheries in the world’s oceans (1950-2005)

(see text for details)
SUMMARY

This analysis was commissioned by the PROFISH Program of the World Bank as one of a number of possible indicators that could potentially be used to assess the governance of fisheries at the country level. An indicator of the state of fisheries at the country level can also assist fisheries managers and civil society to assess the country’s progress towards key goal for sustainable fisheries – the recovery of fish stocks as called for in the World Summit on Sustainable Development Plan of Implementation and in various United Nations General Assembly resolutions.

The results rely both on the quality of the data used and the hypothesis underlying the analysis. As the quality of the data is highly variable and the hypothesis is based on a general fishery development model which may not account for variability between countries, it is strongly cautioned that the results presented in this report should not be taken as a definitive statement. The results are presented rather as means of framing a constructive dialogue on national fisheries reform and exploring how a more transparent and accurate account of the state of the marine fishery sector at country level may foster political will for improved governance of marine fisheries. The diagnostics presented in the report should ideally be tested and supplemented at country-level by more detailed subsector, fishery and stock levels. This will build a more detailed and robust picture of the national state of fisheries and can contribute to FAO’s efforts to track the state of world and regional fishery resources.

As many of these resources are shared by coastal and fishing nations within a Large Marine Ecosystem (LME) and often subject to management measures that have been internationally agreed (e.g. in regional fishery bodies), a common metric may assist countries to jointly gauge and demonstrate their progress towards maintaining or restoring fishery resources and hence, the performance of their policies in that respect. Such a metrics may also assist countries to improve accountability for stewardship of fisheries resources at the country level. It can also promote the identification of information gaps and foster investment in the scientific underpinning of fisheries management, in better fishery statistics, and in improved transparency and knowledge of fisheries. Finally, it would also help international financial institutions and development agencies to better assess the impact of their activities.

This preliminary study is an analysis of the development patterns in the fishery landings database of FAO (1950-2006) against a purely empirical and qualitative development model. The model is used to determine if coherent conclusions can be made regarding the state of development of the fisheries (and eventually regarding the state of underlying resources) based exclusively on this dataset. The analysis is made on selected resources aggregates: Bottom Fishes; Small Pelagic Fishes; Other Fishes; Crustaceans and Cephalopods as well as their total. The analysis proceeds from the global level to the regional and country levels and from the total of the selected resources to each resource category.

The fishery development model used as template consists of 5 phases: un-developed, growth, mature, senescence and, possibly, recovery. The trends in landings and in the relative annual rate of increase (ROI) are used to distinguish between the phases. The ROI is nil during periods of stagnation and at maturity. It is maximal in the middle of the growth phase and decreases as the sector reaches the empirical maximum possible for the set of resources considered, within the prevailing productivity and socio-economic conditions.

At world level, the analysis shows that the level of average maximum landings of “Bottom Fishes” that could be produced under the prevailing conditions was being reached. The landings of “Small Pelagic Fishes” seem to have been reached about a decade ago. The landings of “Other Marine Fishes” are also levelling off while those of crustaceans and cephalopods are still growing.
At regional level, and looking at all selected resources together, a synoptic representation of the situation in FAO Main Fishing Areas reveals a number of differences between areas:

a. In Areas 21 (Atlantic NW) and 47 (Atlantic SE) the landings peaked and the growth rates reached zero early in the period examined (in the 1960s and 1970s), showing a steady decline after wards. Area 21 is also the area in which the major collapse of bottom finfish resources (particularly cod) has been observed. Area 47 (Atlantic SE) has been heavily fished for decades, particularly in Namibia, prior to its independence in 1990.

b. Many areas have apparently reached their maximum during the second half of the period (after the mid-1970s) and have oscillated at that level, showing some sign of sustained decline in the last one or more decades: these include Areas 27 (Atlantic NE), 31 (Atlantic WC); 37 (Mediterranean and Black seas) ; and probably 61 (Pacific NW) and 81 (Pacific SW).

c. Many areas seem to be close to their maximum but have not shown any sustained decline yet even though the growth rates are close to zero: areas 41 (Atlantic SW), 51 (W Indian Ocean), 67 (Pacific NE), 77 (Pacific EC) and probably 87 (Pacific SE).

d. Areas 57 (E Indian Ocean) and 71 (Pacific WC) do not show yet any clear maximum and the growth rates, despite having decreased are still positive on average.

The same analysis has been conducted for “Bottom Fishes”, leading to some shifts between categories. Overall, the situation appears worse.

At national level, and as a preliminary step, more than 200 areas have been examined for trends in their total selected landings and the analysis of the patterns indicate that, during the last decade, 30% of the areas are still “developing”; 30% are “mature” and 40% are already “senescent”, some of which for many decades.

The report examines some practical and policy implications of the findings in relation to sector development and state of the underlying resources. It also briefly indicates the aspects of the sector that may need to be investigated as a priority by the countries depending on the development phase they are in.

This report is to be considered preliminary as only a partial analysis has been conducted. A more comprehensive report will be produced in due course. The aim of this preliminary report is to present the methodology, the character and possible interpretations of the results obtained, and to stimulate a dialogue between the World Bank and the coastal countries on the need for fisheries reform. It is stressed that the country-level diagnostic presented needs to be confirmed at country level, in collaboration with national authorities, scientists and fishing industry which are the repositories of the more detailed and specific knowledge required to revise the diagnostic and place it in context.
1. INTRODUCTION

1.1. CONTEXT

World Bank activities in support of sustainable fisheries focus primarily at the country level as countries are the main point of articulation for Bank activities. As part of its services to client countries the Bank provides a range of indicators for client counties to gauge progress towards national objectives. These metrics include indicators\(^1\) of governance and business climate. However indicators of the status of natural resources such as fisheries, forests and ecosystem health are either deficient or less than robust.

This analysis was commissioned by the PROFISH Program of the World Bank as one of a number of possible indicators that could potentially be used to assess the governance of fisheries at the country level. An indicator of the state of fish stocks at the country level can also assist fisheries managers and civil society to assess the country’s progress towards key goal for sustainable fisheries – the recovery of fish stocks as called for in the World Summit on Sustainable Development Plan of Implementation (see section 1.2) and in various United Nations General Assembly resolutions.

This report presents the preliminary results of an analysis of global marine landings undertaken to explore the value of a comparative indicator of the state of exploitation of marine fisheries resources at the level of countries and regions. Because the analysis is based exclusively on the landings statistics submitted to FAO by member countries, it suffers from the limitations of these data. The analysis also relies on a hypothesis that the long term trends in these landings statistics reflect the development of the sector on an evolving (geographically expanding and ecologically changing) resource base. The hypothesis and the metrics presented will benefit from additional testing at country level using the more detailed information available to national fisheries authorities and civil society.

The report provides a framework for dialogue on three questions: (i) what is the utility of a country-by-country indicator of the state of the fishery sector and its resources?; (ii) can a robust indicator be developed based on internationally available data sets, such as the FAO landings statistics?; (iii) what additional data, or enhancement of existing data, would be necessary to develop a robust country-level indicator of the state of fisheries and related resources?

As emphasized above, the results presented in this report rely both on the quality of the data used and the hypothesis underlying the analysis. As the quality of the data is highly variable and the hypothesis is based on a general fishery development model, that may not account for variability between countries, it is strongly cautioned that the results presented in this report should only be taken as a means of framing a constructive dialogue at national level on fisheries reform and on how a more transparent and accurate account of the state of the national marine fishery sector can help build political will for improved management of marine fisheries. The analysis of trends in exploitation of stock and resource assemblages presented in the report will ideally be tested and supplemented at country-level by additional stock-specific analyses of the major commercial fisheries. This will build a more detailed and robust picture of the state of fisheries resources at national level and can contribute to FAO’s efforts to track the state of world fishery resources.

1.2. WHY IS THIS ANALYSIS NECESSARY?

The degradation of marine fisheries resources has been extensively documented together with the problems of governance at the origin of the problem (e.g. in Larkin 1972; Stevenson 1973; Johnston 1992; Garcia 1992; FAO 1993, 1997, 2002, 2007; Alverson and Larkin 1994; Walters 1995; Garcia and Grainger 1997; Garcia and Newton 1997; Mace 1997; Williams 1998; Sutinen and Soboil 2003; Worldwide Governance Indicators (http://www.govindicators.org); Doing Business indicators (http://www.doingbusiness.org/).
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and Garcia 2005). The FAO report on the State of Fisheries and Aquaculture (SOFIA) provides a comprehensive biennial review of the state of the sector and of the key issues affecting it. The international conferences such as the FAO Committee on Fisheries and the United Nations General Assembly, (UNGA) have greatly helped in building a broad international consensus on the need for an urgent and profound reform of fisheries governance.

As part of its efforts to foster reforms in the governance of fisheries resources the World Bank seeks metrics to establish baselines and indicators for measuring progress towards internationally agreed goals for country level state of fisheries resources, such as those supported by countries in the World Summit on Sustainable Development Plan of Implementation (WSSD-POI):

“31. To achieve sustainable fisheries, the following actions are required at all levels:
(a) 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;”

In reporting their landings, fishing nations do not indicate whether they originate from inside exclusive economic zone (EEZs) or from the high seas. Nonetheless, according to FAO (1995:14) estimates, the percentage of high seas catches increased from 5% in the early 1970s to slightly over 10% in the 1980s. Maguire et al. (2006) indicate that the landings from the so called “high-seas resources” are of about 11 million tonnes (about 12% of the world marine reported landings), a significant part of which comes from highly migratory and straddling stocks and is therefore taken within EEZs. The latest issue of SOFIA indicates that 13% of marine catches in 2006 were taken outside EEZs, representing the highest figure in recent decades. This underlines the fact that countries are predominantly and directly responsible and accountable for the state of exploitation of most marine fishery resources. The deterioration of many fishery sectors and resources contributes to significant economic losses in countries. These losses are estimated at some $50 billion annually, or over $2 trillion over the last three decades (World Bank 2009).

As many of these resources are shared by coastal and fishing countries within large marine Ecosystems (LMEs) and are often subject to international management arrangements (e.g. through regional fishery bodies), a common metric can assist countries to jointly gauge and demonstrate their progress towards maintaining or restoring fishery resources and hence, the performance of their policies in that respect. Such a metrics may assist countries to improve accountability for stewardship of fisheries resources at the country level. It can also promote the identification of information gaps and foster investment in the scientific underpinning of fisheries management, in better fishery statistics, and in improved transparency and knowledge of fisheries. Finally, it would also help international financial institutions and development agencies to better assess the impact of their activities.

Despite the valuable and systematic work undertaken by FAO for decades to monitor world fisheries and resources², the conventional stock assessment information is neither timely nor comprehensive enough. In terms of stock coverage, more than one thousand five hundred taxonomic categories are recognized in the FAO landings database and, given the wide geographical range of some species, there are several times more individual “stocks” or discrete fished populations, for most of which no conventional stock assessment can be conducted. This suggests that in order to measure progress towards the WSSD POI objective to “restore stocks to levels that can produce the maximum sustainable yield”, complementary, simpler and more aggregated indicators are necessary. In addition, as fishing capacity can often move rapidly between resources, indicators at sector or subsector level are needed to complement the stock-by-stock information. An effort in that direction was undertaken more then a decade ago by Grainger and Garcia (1996) who analysed the trends in the FAO landings data, aggregated by main resource types, to produce a global and regional assessment. The approach is extended in this study, presenting and analysing the data aggregated at country level.

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² Since 1974, FAO has compiled thirteen detailed reports on the state of marine resources. The State of Fisheries and Aquaculture (SOFIA) is published every two years. The FAO-led global Fisheries Resources Monitoring System (FIRMS, http://firms.fao.org/firms) is gradually completing its inventory of identified stocks and fisheries and of their evolution.
An alternative approach was explored by the World Bank (Hoshino and Kelleher, unpublished) prior to undertaking this analysis. The sequence of reviews of the state of marine fishery resources published by FAO between 1974 and 2005 were examined to assess the possibility to establish coherent time series to track the evolution of fish stocks within a national perspective. However, the variation with time in the stocks covered, their state, and the level of uncertainty about that state precluded the establishment of usable time series and stressed the need to explore a more comprehensive, stable and replicable approach.
2. THE APPROACH

In the early 1970s global reported marine landings were about 50 million tonnes/year and it was estimated that global ocean fisheries could yield 80-100 million tons/year if properly managed (Gulland 1971). A brief account of the estimation process is given in Annex 1. Between 1970 and 1990, despite increasing geographical expansion and technological developments, the annual relative rate of increase in world fisheries production has progressively decreased. Since the early 1990s, global reported landings have oscillated around 80-85 million tonnes, signalling the end of the intensive growth phase of world marine capture fisheries. Meanwhile, the production of world aquaculture grew at a rate of about 9% per annum, reaching 52 million tonnes in 2006 and capture fisheries production in inland waters remained around 10 million tonnes in 2006 (FAO 2007).

The most important stocks have been assessed using a range of techniques and the results have been compiled in regional and global reviews (e.g. Grainger and Garcia 1996; Garcia and Newton, 1997; FAO 1997, 2002, 2007; Maguire et al. 2006). In all, about 25% of the stocks are still increasing production, 50% have reached maximum production and 25% are overexploited, depleted or slowly recovering. In all, 75% of the stocks need urgent policy and management action and, except in a few countries, this situation has changed little in the last decade despite the concerns and commitments expressed at the highest levels by coastal and fishing nations (Pitcher et al. 2008, 2009).

This study analyses landing patterns against a purely empirical qualitative development model to determine if coherent conclusions could be made regarding the state of development of the fisheries (and eventually regarding the state of underlying resources) based exclusively the analyses of landings data as reported by member countries of FAO. The analysis proceeds from the global level to the regional and country level and from the total of the selected resources to each resource category. The global to local progression is intended to deal with the expectation that the data would become ‘noisier’ at the lower aggregation level and that it would be, therefore, prudent to nest the country-level diagnostics within coherent regional diagnostics.

2.1. THE FISHERY DEVELOPMENT CYCLE

Most if not all economic activities develop and decline in “business cycles” (Schumpeter 1939; Marchetti 1987) with phases of expansion, crisis, recession and, possibly, recovery, resulting in the well known “boom and bust” pattern of development. Fisheries development is also affected by fluctuations related to changes in policies, technology, markets as well as resources fluctuations.

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3 Annex 1 provides a brief summary of the estimates of the potential of the global ocean fisheries.
4 For example, significant efforts are being made in several countries including Australia, New Zealand, Iceland, Norway, Canada, South Africa, and Peru. Many are adopting the Ecosystem Approach to Fisheries (FAO, 2002). However, the global situation is still unsatisfactory and possibly worsening through illegal fishing, flags of convenience, growing vessels efficiency, insufficient flag and port States control, and often, ineffective RFMOs.
5 Despite their name, these business cycles are usually not “cyclical” i.e. not regular and not predictable. However, in fisheries, they are also triggered by natural resource oscillations which may be partly predictable (Klyashtorin 2001)
Box 1. Single and aggregate fishery development models

The historical development of a single-stock fishery on one particular stock as described for example by Csirke and Sharp (1984) is described in the figure below and a more detailed description of each phase is given in Annex 2.

**Figure 1:** Development cycle of a single stock fishery. Redrawn from Csirke and Sharp (1984). Courtesy FAO

At the higher levels of aggregation of a subsector, country, region, or ecosystem, the development pattern may differ slightly because the differences in the single fisheries developments and sequential overfishing may generate smoother aggregated trajectories and a flatter-topped pattern as the one described by Welcomme (2001) for large inland water bodies.

**Figure 2:** Development cycle for aggregated fisheries and related management objectives. Redrawn from Welcomme (2001). Courtesy FAO-Fishing News Books. The sequential overfishing (if it occurs) is hidden in the changing composition of landings. The simultaneous collapse of all fisheries appears unlikely, unless the environment is also destroyed as in the Aral Sea or severely compromised as in the Black Sea. However, a severe drop in production is to be expected when all potential resources in the area are overexploited and the ecosystem system has reached the limits of its adaptive capacity.
Empirical observations (confirmed by the data used in this study) have led to the recognition of a development model for single fisheries (Larkin and Willimovsky 1973; Csirke and Sharp 1984; Caddy 1984). The model conceives fisheries as evolving through phases of pre-development (or underexploitation), growth (or development), full exploitation, overexploitation, collapse and recovery (cf. Box 1; Figure 1 and Annex 2). These phases depict the progressive “colonization” and eventual degradation of the single resource by the fishery and can usually be detected, despite fluctuations, in the long-term trend in the landings. The observation of the historical pattern informs about the likely state of the underlying resource.

Aggregating the production of many fisheries on many species at sector, national, regional or global level, the process observed is one of progressive colonisation of the resources aggregates in the related fishing areas (Box 1, Figure 2). Similar evolutionary phases are logically expected, reflecting the interaction between the limited resource and the developing fisheries in the process of “colonization” of the underlying ecosystems. Indeed, Grainger and Garcia (1996) showed that the conventional phases of the fisheries development cycle could be detected in the landings obtained from the 200 main resources aggregates used by world fisheries (Figure 3, top), and used this fact to characterize the development level of the main world resources from 1950 to 1994. In this analysis, a phase graph has been added to relating the growth rate to the landings (Figure 3, bottom).

As illustrated in Figure 3, the rate of growth of a fishery (as measured by its landings) increases rapidly at the beginning of the growth phase. It is highest somewhere in the middle of that phase and decrease with time towards zero as the potential for growth is used up. Albeit disturbed by fluctuations, this long-term pattern is clearly visible in most datasets. The medium-term fluctuations

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6 It would be maximal at exactly 50% of the maximum level if the growth phase was a perfect logistic curve (i.e. S-shaped).
may be related to natural oscillations of the resource base or to new economic development opportunities. However, the long term trend towards some asymptote, particularly under a market economy, is most likely connected to the natural limits of the composite resource base and the progressive reduction with time of the number and size of stocks that are still able to produce substantial increases in landings. The pattern and trends of the landings, thus indicates the pace at which the developing exploitation approaches its saturation point or, in other words, its operational maximum production under the prevailing conditions. The argument was used by Garcia and Newton (1997) as an indication that the world production was probably approaching its maximum at that time.

The examination of the data available at global, regional and Home Area levels in the initial steps of this study has confirmed the general pattern shown in Figure 1 (see also section 4.2) putting in evidence, however, in many cases, the importance of medium-term oscillations. As a consequence, the aggregate fisheries development model of reference has been modified as shown in Figures 4 and 5.

![Figure 4: Aggregated fisheries development model used in this study. The roman numbering of the phases corresponds to Figure 3](image)

![Figure 5: Landings phase graph. The starting (black circle) and ending (grey circle) points of the series are highlighted. The overall trajectory is materialized by the thick dotted line. The recovery part, (thin dotted line) has not yet been observed.](image)
2.2. **RELATION WITH THE STATE OF RESOURCES**

The relation between the development cycle and the state of the underlying resources is complex. The shape of the cycle may be determined by the level of resources available and their reaction to exploitation but also by availability of manpower, technology, capital and markets. In the longer term, however, it is clear that virgin resources are more abundant than exploited and depleted ones, and that abundance declines as removals increase (being aware that natural fluctuations may seriously distort this picture). Figures 1 and 2 show the expected long-term evolution of abundance expressed as catch rates (or catch per unit effort, cpue) during the development cycle.

Contrary to the conventional production model (Annex 3), the parameters of the fisheries development model, i.e. its precise shape, the timing of the critical bending points, and the slopes of the various sections, are not precisely determined and, therefore, the trajectories cannot be precisely forecast\footnote{But Marchetti (1987) used the logistical (S-shaped) left part of the cycle to calculate its parameters and forecast its development and demise}. Nonetheless, a central assumption of this work is that, *in hindcast*, the observed historical trajectories inform about the underlying state of the resources. It is assumed that, while medium-term fluctuations may reflect climatic or socio-economic fluctuations of fisheries development drivers, the longer-term pattern reflects the relative “composite” state of the underlying resource mosaic. More details on this issue are available in the discussion (section 5.2). In addition, it should be noted that the oscillatory landings asymptote bears no relation with the conventional MSY concept and might be considered a composite form of Maximum Average Yield (MAY, sensu Mace 2001).

2.3. **THE CONCEPT OF “HOME FISHING AREA”**

As noted above, the landings statistics in the Fishstat database for a particular country refer only to the FAO Main Fishing Area of origin. The catches may be from the EEZ, but could also be from the waters of adjacent countries where the vessels of that country have fished, or from the high seas in that FAO Area. For this reason it has been necessary for the purposes of the analysis to designate a “Home Fishing Area” (hereafter the Home Area, see Fig 6), that includes the EEZ of the country concerned and the other fishing spaces within that FAO Area to which the country’s vessels have access.

Some countries border more than one FAO Area and therefore have more than one Home Area. For example, France’s Atlantic coast bounds FAO Area 27, while its Mediterranean coast bounds FAO Area 37. The landings selected for France are those made in the FAO Area 27 (France 27-Northeast Atlantic) and 37 (France 37-Mediterranean). Landings reported by this country from other FAO Areas (Areas 58, 51, 34, 21, 41, 47, and 48) have been excluded from the analysis. The complete list of Home Areas is given in Annex 4.
Figure 6: relation between FAO Areas and Home Areas. In dark grey, the extension of the resources, often corresponding to the end of the shelf

The landings reported by a country to FAO are assumed to reflect to some extent the state of the composite resources living in the Home Area, but not necessarily in the total FAO Area concerned. Clearly, in some cases the resources in one Home Area may not be affected only by the bordering country concerned (Figure 6, left). In other cases, catches are made essentially by the coastal country concerned (Figure 6, right). A more detailed discussion on these implications is provided in section 5.2.1.d. It must be emphasized that, as the Home areas may extend beyond the waters strictly under national jurisdiction, considerable caution must be exercised in drawing purely national implications from the study.

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8 The correspondence between the two depends on how mobile the resources are.
3. THE DATA

3.1. DATA SOURCE

The data used has been extracted from the FAO Fishstat Plus data base\(^9\), specifically the Capture Production dataset (1950–2006). The database is compiled from information provided to FAO by fishing nations. The dataset is the only global and publicly accessible data set on reported fishery landings. The information is provided in accordance with internationally agreed protocols of the international Coordinating Working Party on Fishery Statistics (CWP)\(^{10}\) and the reporting parameters affect the utility of the data for the purposes of describing the level of development of national fisheries and drawing conclusions about the state of the underlying resources on a country-by-country basis. The reporting protocol was agreed long before the adoption of the 1982 Law of the Sea Convention (LOSC). As a consequence, countries’ reports on landings from vessels flying their flag do not distinguish between fish taken in the EEZs (or declared fisheries zones) and the high seas, but report the origin of the landings with reference to the FAO Major Fishing Areas (hereafter, the FAO Areas) \((\text{Figure 7})\).

\[\text{Figure 7: FAO Major Fishing Areas}\]

Notwithstanding its known and alleged limitations, the Fishstat dataset has been shown to contain information about the development trends of fisheries, consistent with other sources of knowledge on such trends (Grainger and Garcia 1996; Caddy and Garibaldi 2000; Garibaldi and Caddy 2004). It is therefore tempting to conclude that the different sources of error in the data are not sufficient to significantly distort the main development trends if due caution is exercised in using the data.

The FAO Areas concerned by the analysis are: the Northeast, Northwest, Southeast, Southwest, Eastern Central and Western Central Atlantic and the Mediterranean/Black Sea; the Eastern and Western Indian Ocean; and the Northeast; Northwest, Eastern Central, Western Central, Southeast and Southwest Pacific (15 areas in total). The Arctic and Antarctic areas have been excluded from the analysis.

\(^9\) Software and data available at \(\text{http://www.fao.org/fishery/statistics/software/fishstat}\)

\(^{10}\) \(\text{http://www.fao.org/fishery/cwp/en}\)
The capture production of all countries and other political entities having reported landings to FAO have been considered. When a country bordered more than one Home Area, these were processed separately. Canada, for example has coastline bounding FAO Fishing Area 21-Northeast Atlantic and 67-Northeast Pacific. In addition, these data have also been combined describe the trends in total fishery sector production. Aggregations were also made for each FAO Area and at world level.

The data series of a few countries or political entities have been interrupted when these entities ceased to exist as reporting units (e.g. USSR, Yugoslavia) and were excluded from the analysis. The data series for the new countries emerging or re-emerging (e.g. Slovenia, Serbia-Montenegro, Ukraine, and Russia) were too short to be used for this analysis.

3.2. DATA AND INDICATORS

3.2.1. ISSCAAP Categories

The Fishstat Capture production data set contains information reported on 1640 statistical taxonomic categories corresponding to the species, genus, family or higher taxonomic level 11. These species are further grouped into categories agreed as International Standard Statistical Classification of Aquatic Animals and Plants (hereafter called ISSCAAP categories). A significant proportion of the data is reported to FAO as “Miscellaneous” or “Unidentified” fish. The landings are in metric tons, equivalent live weight.

This preliminary study is purposely limited to fisheries on conventional resources (e.g. bottom and small pelagic fishes) which are those offering the longer time series. Except where there are very large shelves (e.g. in the North Sea) these fisheries operate within the EEZs and adjacent waters. For this reason, the ISSCAAP categories 31, 32, 33, 34, 35, 37, 39, 42, 43, 44, 45 and 57 (cf. Annex 5) were used as filters to extract the data from the FAO database to constitute the resources categories listed below. Large pelagics, mammals and other highly migratory species have been excluded from the analysis as fisheries for these species tend to range throughout the high seas. Bivalves were also excluded.

3.2.2. Categories of resources used in the analysis

The landings (in metric tonnes, round weight) for five categories of resources and the total landings were extracted from the Fishstat Capture Production dataset. All landings values are expressed in metric tonnes (referred to as “Landings” in the text and figures and “L” in Excel files). The landings values below 0.5 tonnes have been ignored.

The reported landings in Home Area are assumed to indicate the level of development (growth) of the fishery towards the “maximum” possible in the Home Area under the given productivity, management regimes and economic conditions. In order to reduce high frequency natural and sampling variability, and to buffer the delayed responses of the resources mix to changes in fishing or the environment, the landings were smoothed by a simple running average on five years 12. The resources categories were established as follows, indicating their relative importance in percentage of the global reported capture fisheries landings on average during the last decade (all categories and all areas included):.

- a. Bottom Fishes (demersal finfish): ISSCAAP categories 31 (flounders, halibuts, soles), 32 (cods, hakes, haddocks), 33 (miscellaneous coastal fishes), 34 (miscellaneous demersal fishes). For the purposes of the analysis, it was assumed that category 33 contains

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11 SOFIA 2006 indicates that the number of species items appearing in the FAO database has been growing at an average annual rate of 5% over the past eight years from 1205 in 1999 to 1640 in 2006, of which 1487 are taken in marine fishing areas. The percentage of catches reported at the species level has also increased even though about 37 percent of global catches are still not reported at the species level.

12 The number of years on which to calculate the average was chosen as a compromise evidencing the trends clearly enough while not reducing too much the length of the time series.
essentially demersal and benthopelagic fish. This category accounted for some 24% of the landings,

b. Small Pelagic Fishes: ISSCCAP categories 35 (herrings, sardines, anchovies) and 37 (miscellaneous pelagic fish). For the purposes of the analysis, it was assumed that this last category contains essentially small pelagic species. This category accounted for some 41% of the landings.

c. Other Marine Fishes: ISSCCAP category 39 (marine fishes not otherwise identified). It is suspected that this category contains essentially small individuals and species of the bottom fishes because small pelagics are usually caught and landed in large quantities and small number of species, easily identifiable. Nonetheless, in the absence of a definitive clue, it was not considered possible to split these landings into bottom fishes and small pelagic fishes with any degree of confidence. The data were therefore kept separate. This category accounted for some 13% of the landings.

d. Crustaceans: ISSCCAP categories 42 (crabs, sea spiders), 43 (lobsters, spiny rock lobsters), 44 (king crab, squat lobsters), 45 (shrimp, prawns). This category accounted for some 6% of the landings.

e. Cephalopods: ISSCCAP category 57 (squid, cuttlefishes, octopuses). This category accounted for some 4% of the landings.

f. Total Fishes: ISSCCAP Categories 31, 32, 33, 34, 35, 37, 39, 42, 43, 44, 45 and 57. This category accounted for some 87% of the landings.

Crustaceans and Cephalopods categories were also kept separate as they have been the basis of more recent specific fisheries developments and they may decrease if overfished but also increase with fishing pressure as their main predators are decimated.

3.2.3. Growth rates

For each of the time series of landings (L) the annual rate of increase (R) was calculated as follows:

\[ R(t) = \left[\frac{L(t) - L(t-1)}{L(t-1)}\right] \times 100 \]

In addition, as for the landings, a smoothed series (R5) was also calculated using the averaged series of landings (L5):

\[ R5(t) = \left[\frac{L5(t) - L5(t-1)}{L5(t-1)}\right] \times 100 \]

3.2.4. Other indicators

In each FAO Area, the yearly landings were used to calculate an index of the state of development as follows:

Relative landing = RL(t) = \left[\frac{L(t)}{L_{\text{max}}}\right] \times 100.

L_{\text{max}}, the Maximum Average Yield (sensu Mace 2001), was calculated as the average of the 5 highest yields in a series of 10 consecutive years corresponding to the decade during which long term trend in growth rates crossed the zero-growth line. The Values of RL(t) were then colour-coded using the following key: RL < 50% = dark green; 51% < RL < 90% = light green; 91% < RL < 100% = yellow; 100% < RL < 90% = yellow; and RL < 90% = red. The limits of the categories were arbitrary selected but intended to separate early development (dark and light green) from Maturity (yellow) and senescence (red).

Finally, in order to have a more synthetic indicator of the global state of world resources, the proportions of the areas under each development phase were calculated each year, weighting the coding of each area by the corresponding L_{\text{max}} value. This was intended to give more weight in the assessment to those areas with the largest contribution to world production.
4. RESULTS OF THE ANALYSES

In the following sections, some general trends in the selected resources categories will be presented first, to show their relative importance in the total landings and their evolution. Based on the new variant of the aggregated fishery development model presented above, diagnostics on the state of the fisheries are then presented, starting from the highest aggregation level (the world), drilling down to the lower regional and Home Areas levels. At the global and regional level, results for the three main resources categories (Total Fishes, Bottom Fishes and Small Pelagic Fishes) will be presented. At national level, the amount of information to process is massive and this first stage analysis addressed the Total Fishes level only.

4.1. GLOBAL TRENDS

4.1.1. Trends in Total Fishes

Figure 8 (left) shows that the landings of Total Fishes, representing more than 80% of the total marine reported landings, have increased regularly, with some oscillations, until the mid-1990s, stabilizing around 70 million tonnes for the last decade. The four subgroups have evolved in the same way. The landings of a few large stocks of highly variable small pelagic species\(^\text{13}\) are obviously responsible for most of the low frequency oscillations visible at global level (Garcia and Newton 1997) and they have stabilized since the mid-1990s at about 30-35 million tonnes. They may even have slightly decreased during the last decade but considering the variability of this group, this decrease may be temporary. The landings of Bottom Fishes have stabilized earlier, since the mid-1980s, around 20 million tonnes/year.

The landing of Other Fishes, composed of fishes not better identified, have followed a similar pattern, stabilizing since the mid-1990s at around 10 million tonnes. This category contains unknown proportions of bottom and pelagic fishes. The conspicuous long term oscillations affecting the Small Pelagic Fishes are not present in the Other Fishes category, indicating perhaps that the main small pelagic species responsible for these oscillations may not contribute much to this category. The reported landings of crustaceans and cephalopods have reached about 5 and 3.5 million tonnes respectively but are still increasing steadily.

4.1.2. Trends in landings composition

The proportions of these groups in the Total Fishes category (Figure 8, right) have fluctuated with little change overall. Since the beginning of the time series, there has been a slight decrease in the percentage of Bottom Fishes from about 37% to 30%. As this group contains some of the most impacted high value resources, a decrease in relative abundance was expected. The Small Pelagic Fishes have oscillated between 45 and 60%.

The proportion of Other Fishes has increased from more than 1 million tonnes to about 10 million tonnes. This evolution hides two main dynamics: (1) the increase of the amount of low-value small-size bycatch as a consequence of increased fishing as well as reduction of discards, particularly since the years 2000 (Kelleher, 2005); (2) an improved sorting of the bycatch (or diversification of targets)\(^\text{13}\) anchoveta, Alaska pollock, Chilean Jack mackerel, South American pilchard and Japanese pilchard.
as the market price of secondary species has improved (due to increased scarcity). This diversification appears clearly in the list of species reported to FAO\textsuperscript{14}.

There is no objective clue to split, even roughly, the Other Fishes into the other categories, particularly Small Pelagic Fishes and Bottom Fishes, without direct observations in the field. Reliably splitting historical landing data retroactively in the absence of any related metadata would be questionable considering the wild assumptions needed. The correlation between the various trends (Figure 9) is obviously good. It is slightly better with the bottom fish because the variability patterns are closer. The correlations between detrended values (not shown) disappear, leaving only a larger spread of residuals in the case of Small Pelagic Fishes.

\textbf{Figure 8}: Global trends in landings (Left) and proportions of the different categories (right).

\textsuperscript{14} The number of species items appearing in the FAO database has been growing at an average annual rate of 5\% over the past eight years from 1205 in 1999 to 1640 in 2006. The percentage of catches reported at the species level has also increased even though about 37 percent of global catches are still not reported at the species level.
The exponential increase in the landings of crustaceans and cephalopods reflects perhaps both: (1) an improved separation from the other landings as well as the development of specific fisheries towards these species as the world market developed, and (2) their relative increase in the ecosystem as a consequence of the reduction of their predators (Pauly et al, 1998; Sainsbury 1987). In the second case, the cascading effects of the Canadian cod stocks collapse on the food web have been well documented (Bundy and Fanning 2005; Frank et al. 2005; Fisher et al. 2008).

4.2. TYPICAL PATTERNS

The observation of the data, at Home Area, regional or global level shows the basis for selecting the empirical aggregated fisheries development model given in Figures 4 and 5. Examples of the trends in landings and relative rates of growth are shown in Figure 10 (left column). The world and the Belgium examples show two opposite but complementary parts of the development model, with the initiation and growth phases in the first case and a long senescence on the second one. The Denmark offers an example of a quasi complete development cycle. Other quasi complete cycles are given by Area 34-Bottom Fishes and Area 81-Bottom Fishes (Annex 7). The latter offers one of the very few examples of a 20-year phase of un-development followed by 20 years of fast development a decade of maturity and perhaps some signs of senescence. No clear example of a full recovery phase was found. The closest example of a complete loop is given by Albania (Figure 10, bottom) even through the “recovery” phase has not yet brought production back to the historical maximum. Various types of fluctuations can be seen in all these figures. The longer-term trends are given by the simple polynomial trend line. The medium-term fluctuations appear more clearly in the 5-year running average trend line and periodicities around 5 years (which could be spuriously generated by the smoothing process) should be disregarded unless they clearly appear in the raw data. The high frequency noise is very apparent in the growth rate.

The passage from exponential to asymptotic growth of the landings is clear in the majority of the diagrams. This observation is greatly assisted by the simultaneous observation of the growth rates, as their zero-values characterize extremums in landings. The reaching of an apparent asymptotic landing level when the long term trend in growth rates is zeroing, is taken as a clear sign that the saturation level, or empirical maximum of the Home Area under the prevailing conditions, is being reached. It was found that the elaboration of a phase graph, correlating landings and growth rates helped in identifying the development phase, particularly in presence of strong oscillations. (Figure 10, right column)
The real data supports therefore the description of fisheries development elaborated in section 2.1 as a sequence of fast growth phases separated by short periods of stabilisation (or decline) where the growth rate is nil or negative. The medium-term fluctuations (particularly in growth rates where they are amplified) look similar to those of the general model, with “mini phases” of growth, maturity and decline and rapid transition to the next cycle. These fluctuations could be driven by economic decisions or by the environment. As the sector tends to develop rapidly on medium-term natural fluctuations and sometimes collapse with them, the difference between the two possible mechanisms is irrelevant in the framework of this study.

It is important to note that the oscillatory asymptote towards which the landing curve tends bears no relation to the conventional concept of MSY. The main increasing trend in landings may result from: (i) increased fishing effort (as in a conventional production model); (ii) expansion of the area fished (and underlying exploitable biomass), within the EEZ or and in the adjacent FAO Area as the grounds already in use become less profitable; (iii) change in fishing strategies, finding new targets (“fishing through the food web”) as well (iv) true ecosystem modifications under fishing pressure (“fishing down the food web”). The maximum is therefore one of the pragmatic maximums that the area could offer given various exploitation strategies and climate variation patterns (see section 5.2.1 for a discussion of this issue). It is also important to note that linearity, homogeneity and strict reversibility are not assumed. It is only assumed that the critical situations may be corrected but the trajectories and end results of the correction process cannot be specified too precisely.

4.3. WORLD-LEVEL DIAGNOSTIC

In this section, we will look first at the state of development of the world fishery looking at the Total Fishes category, and then at the fisheries exploiting the various resource categories. Figure 11 (top) shows that, since the mid-1990s, total landings have been level and the rate of growth has been stagnated around the zero level, indicating that world fisheries have probably reached their maximum extension. This has been the conclusion of all global reviews of the state of world resources (Garcia and Newton 1997; Grainger and Garcia 1996; World Bank 2009) and is in line with the assessment made by FAO in its biennial resources review (SOFIA, FAO 2007). It might be useful to recall that this picture hides all the tensions present in the various compartments of this global fishery at regional, national, ecosystem and resource levels.

Examining the different resource categories, the following can be concluded:

a) **Bottom Fishes**: For this high value category, the landing curve alone does not show clearly to have reached its maximum but the growth rate has reached zero at the end of the series and the phase graph shows more clearly that the fishery has been oscillating around the maximum for a decade. This would indicate that further expansion of any significant magnitude is unlikely (Figure 11, middle).

b) **Small Pelagic Fishes**: For this low value category, both the landings, the growth rates and hence the phase graph indicate that the maximum expansion has been reached and the fishery has been oscillating around its maximum for about a decade (Figure 11, bottom).

c) **Other Marine Fishes**: The trend is similar to that of the two main resources categories, Bottom Fishes and Small Pelagic Fishes. Since the mid-1990s, the landings have been levelling off and the growth rate has been at or very close to zero (Figure 12, top).

**Crustaceans and cephalopods**: In both cases, the landings are still increasing exponentially and the growth rates still far from zero. In the case of shrimps, a decline is perceptible but the growth rate has been practically constant, on average, for the last 3 decades. In the case of cephalopods, they are apparently stable from the onset. These two groups behave definitely differently from the other three, justifying their separate treatment (Figure 12, middle, bottom).
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

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Figure 10: Left: Typical patterns in landings and rates of increase (ROIs). Reported values, moving average on 5 values and polynomial trend line (2nd degree) for the ROIs. Right: Phase graph. The green and red dots indicate the beginning (1953) and end (2004) of the time series. The hand-drawn red arrow indicates the main trajectory.
Figure 11: World - Landings and ROIs for the Total, Bottom Fishes and Small Pelagic Fishes categories. **Left:** trends. **Right:** phase graphs
Figure 12: World - Landings and ROIs for the Other Fishes, Crustaceans and Cephalopods categories. 
Left: Trends. Right: Phase graphs
4.4. **REGIONAL-LEVEL DIAGNOSTIC**

4.4.1. **Total Fishes**

In this assessment, we consider the state of development all fisheries (on the Total Fishes category) in each FAO Main Fishing Area, excluding polar areas. The type of results obtained is shown in Figure 13. The whole set of representations is given in Annex 6.

![Figure 13](image-url): Area 21-Total Fishes. Trends in landings and growth rates and phase graph

The following observations can be made:

a. In Areas 21 (Atlantic NW) and 47 (Atlantic SE) the landings peaked and the growth rates reached zero early in the period examined (in the 1960s and 1970s), showing a steady decline afterwards. Area 21 is also the area in which the major collapse of bottom finfish resources (particularly cod) has been observed. Area 47 (Atlantic SE) has been heavily fished for decades, particularly in Namibia, prior to its independence in 1990.

b. Many areas have apparently reached their maximum during the second half of the period (after the mid-1970s) and have oscillated at that level, showing some sign of sustained decline in the last one or more decades: these include Areas 27 (Atlantic NE), 31 (Atlantic WC); 37 (Mediterranean and Black seas); and probably 61 (Pacific NW) and 81 (Pacific SW).

c. Many areas seem to be close to their maximum but have not shown any sustained decline yet even though the growth rates are close to zero: areas 41 (Atlantic SW), 51 (W Indian Ocean), 67 (Pacific NE), 77 (Pacific EC) and probably 87 (Pacific SE).

d. Areas 57 (E Indian Ocean) and 71 (Pacific WC) do not show yet any clear maximum and the growth rates, despite having decreased are still positive on average.

It would be useful to have a synthetic global representation of the evolution of all areas. A global synoptic representation with regional resolution has therefore been produced, based on the Total Fishes diagrams of Annex 6. The yearly landings were normalized in relation to the Lmax of each area and colour-coded (cf. section 3.2.4) (Figure 14). The colour ranges are meant to separate early and late development (dark and light green) from maturity (yellow) and senescence (red). The boundaries of the percentage categories are arbitrary.
Figure 14: Total Fishes - Synoptic qualitative representation of the state of development of the Total Fishes category in FAO Main Fishing Areas. See text for the indicator used and the colour coding. The pattern in areas 71 and 57 are approximations because the maximum average landing has not been reached.

Figure 15: Bottom Fishes - Synoptic qualitative representation of the state of development of the Bottom Fishes category in FAO Main Fishing Areas. See text for the indicator used and the colour coding.
On Figure 14, the various FAO Areas (displayed as rows) have been ordered in terms of the chronology of the early development phase (dark green) to show better the progression in the development chronology. It can be seen that the early development phases ended soon after WWII in the Northern Atlantic and between 1960 and 1990 in the rest of the world. The qualitative information remains preliminary for two areas, 71 and 51. For Area 71, the zero growth seems to be being reached (to be checked in a few years). For area 51, the trend still shows substantial positive growth. No extrapolation of the trend was attempted.

While this representation has the advantage to offer a global picture of the state of fisheries development with some visual regional resolution as well as a chronological perspective, it combines the two main types of resources categories, Bottom Fishes and Small Pelagic Fishes which have had different development histories. It can be suspected, therefore that some of the “sustained” growth observed in the Total categories hides an earlier senescence of the high value demersals, compensated by a growth in pelagic fishes production. The analysis should be repeated for the Bottom Fishes and the Small Pelagic Fishes. In this preliminary report, only the Bottom Fishes have been processed.

4.4.2. Bottom Fishes

The set of graphs produced is given in Annex 7. The following observations can be made:

a. In one area (Area 21), the landings peaked and the growth rates reached zero clearly in the middle of the time series with a strong decline afterwards to less than 20% of the peak landings. This is probably the closest to a general collapse of the resource base that such a gross approach could illustrate. This is also the area in which the major collapse of bottom finfish resources (particularly cod) has been observed, in which excessive fishing and unfavourable climatic fluctuations met, and in which, subsequently, fishing strategies shifted to species previously used by cod as preys. This is also the area that exemplifies best the lack of automatic reversibility.

b. Most of the areas seem to have reached their maximum during the second half of the period (after the mid-1970s) and have oscillated at that level, showing some sign of decline in the last one or two decades: Areas 27, 31, probably 37, 34, 61, 77 and 81.

c. Some areas do not show yet clearly to have reached their maximum development, reaching their highest landings in the last decade: Areas 41, 51, 57 and 71. In all cases, however, the growth rates and the phase graph indicate that the development cycle is close to be completed.

It can be seen that the early development phases ended soon after WWII in the Northern Atlantic and between the mid-1970s and mid-1980s in the rest of the regions. This was followed by a decade or two of intensification between 1970 and 1990. After that, the world fishery system for Bottom Fishes has entered into a period of fairly small growth rates heading towards zero. A synoptic representation has also been elaborated (Figure 15).

The information available for Figure 15 was further elaborated to produce, for every year, a weighted distribution of the stages of development observed across FAO Areas (cf. section 3.2.4 for details), using for the representation the same RL categories and colour coding as in Figures 14 and 15. The results are given in Figure 16. This representation gives a clear representation of the progress made towards development until the late seventies and the relative inability of the sector to remain in the maturity phase for very long.
4.5. HOME AREA-LEVEL DIAGNOSTIC

In principle, the same process applied at world and regional level could be applied. However, about 168 Home Areas (see Table 2) have enough data to warrant examination. Many of these have enough data to look at the three main resource categories (Bottom Fishes, Small Pelagic Fishes, and Other Fishes) leading potentially to 500 trend analyses with two graphs each (trend and phase graph). The total number of pictures (potentially more than 1000) and the elaboration of the related synoptic pictures (one per landing category) could not be elaborated within the time available for this preliminary study. As a consequence, the Home Area-level diagnostic was undertaken only for Total Fishes and Bottom Fishes using a slightly different approach to elaborate a synoptic diagnostic.

4.5.1. Development categories

The same process was applied to all the Home Areas with exploitable data. The patterns observed have been classified 6 categories according to the overall pattern and the situation in the last decade (Figure 17), as follows. The elements necessary for the interpretation of such patterns are given in section 5.5.2 and in the Discussion.

a) Developing: The landings increase regularly (most often exponentially) across the whole period, including the last decade). The growth rate trendline remains above zero (even if annual values may cross the zero line during smaller oscillations) with little or no trend. The very last few points may indicate that maturity might be being reached. Indonesia, in its area 77, provides an example (Figure 17: top row).

b) Mature: The landings have increased, with fluctuations, levelling off during the last decade. The growth rates shown a clear negative trends that crosses the zero-growth line during that las decade. Some signs of senescence are sometimes apparent but masked by the short-term oscillations, they cannot be ascertained. Cameroon provides an exemple (Figure 17: second row from the top).

c) Senescent-1: The pattern covers the three main phases of the developpment cycle, (developing, mature and senescent). The growth rate shows a clear negative trend and falls below the zero-growth line some time between 1970 and 1990. Singapore provides an example (Figure 17: third row from the top);

d) Senescent-2: This rare variant of the preceding phase, shows continuous senescence practically from the beginning of the time series. The landings have been decreasing and the growth rate has remained negative for decades. This pattern may reflect chronic unsustainability, perhaps aggravated by progressive disinvestment or progressive disinterest in
and disengagement from fisheries. An example is given by Belgium (Figure 17, fourth row from the top).

c) Indeterminated: This rare situation occurs when, during the whole period, the landings have remained at the same level, on average, with short and medium term oscillations but no trend. The growth rate oscillates around the zero-growth line. This reflects long term stability but offers no clue as to whether the fisheries are undeveloped (stable at low level) or stabilized at some higher level, the position of which, relative to the maximum achievable is not known. The development phase is indeterminated. The indeterminacy could be lifted, obviously, with more data on the biological characteristics of the catch (age, length, etc.). An example is given by USA 77 (Figure 17: bottom row).

Figure 17: Idealized and real development patterns identified at Home Area level.
In addition, in a number of cases, the diagnostic was impossible, for one or more of the following reasons:

a) Very noisy data, both in landings and growth rates, masking the trends:

b) Interrupted time series. This is the case for countries such as USSR and Yougoslavia, which have disappeared, making the assessment of the present situation irrelevant.

c) Too short time series. This is the case with new countries, e.g. as those emerging from the collapse of USSR and Yugoslavia which time series are too short -and often miss the early phases of development- to be interpreted.

d) Turbulent development. Some patterns cannot be interpreted in the standard way because wars or revolutions have created serious perturbations of the trends. These cases need to be examined separately.

When countries have more than one Home Area, the total was also processed but is not included in the results to avoid duplication.

4.5.2. Diagnostic

In total, data for 224 Home Areas have been examined. The complete list of countries and the patterns to which they are associated is given in Annex 8. The results of the observations are given in Table 1 below.

<table>
<thead>
<tr>
<th>Total Fishes</th>
<th>Bottom Fishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Home Areas considered</td>
<td>224 100,0%</td>
</tr>
<tr>
<td>Inconclusive assessment</td>
<td>26 11.8%</td>
</tr>
<tr>
<td>Not assessed</td>
<td>29 9,0%</td>
</tr>
<tr>
<td>Total assessed</td>
<td>169 79,2%</td>
</tr>
<tr>
<td>Of which</td>
<td></td>
</tr>
<tr>
<td>- Developing</td>
<td>52 30,7%</td>
</tr>
<tr>
<td>- Mature</td>
<td>51 30,2%</td>
</tr>
<tr>
<td>- Senescent 1</td>
<td>57 33,7%</td>
</tr>
<tr>
<td>- Senescent 2</td>
<td>9 5,3%</td>
</tr>
</tbody>
</table>

Table 1: Proportion of development phases observed in the last decade for Total Fishes and Bottom Fishes.

A first observation is that there are much fewer areas for which an assessment is possible (107 instead of 169) when only Bottom Fishes are considered. This is related to the fact that: (i) in many historical series, Bottom Fishes have been distinguished from Small Pelagic Species too late to have a long enough time series with enough contrast; (ii) the variability tend to be higher, complicating the diagnostic.

This synopsis indicates that in 39% (Total Fishes) and 45,6% (Bottom Fishes) of the Home Areas examined, the national fisheries appear to be in a senescent state, with a more or less protracted period of decline of their total landings. With relatively less “Developing” and more “Senescent” areas, the situation of the Bottom Fishes category appears to be more concerning.
The decrease of landings (during the senescent phases) has to be interpreted carefully as it may reflect different realities:

a) **Voluntary decreases.** The observed trend may reflect the policy of the country concerned to reduce catches, e.g. for stock rebuilding. The world history of fisheries development tells us that this hypothesis is highly unlikely for any declines observed before the 1980s. The explanation might be a plausible one, in more recent times, for single fisheries. It becomes much less plausible when dealing with the large aggregates of resources examined here.

b) **Economic disinterest.** The trend may reflect a protracted period of fading economic interest in fisheries, leading to decreasing landings. Considering that fisheries are a globalized industry with growing demand, and the documented worldwide growth of fishing capacity, this assumption is rather unlikely in most cases. Moreover, such loss of economic interest might well reflect the decrease of the resource base (see below). The situation might also reflect a loss of competitiveness of the national fishing sector in the related FAO Fishing Area, notwithstanding the state of resources. Considering the widespread use of subsidies by governments in the fishery sector for decades, this should be surprising. The comparison with the patterns shown by neighbouring countries and for the region as a whole could help lifting the uncertainty.

c) **Resource decrease.** Considering the growing demand for fish worldwide, an economic disinterest could be indicating a strong decay in resources as the most likely driver of the situation, particularly since States have started decreasing their level of subsidy.

In all cases, long-lasting senescence may reflect insufficient and failing governance and an urgent need for improved fisheries policy and management to stop the decline and possibly reverse it. While it may also simply reflect a progressive loss of interest for the sector, this could be ascertained with other information at country level.

**Table 1** indicates also that in about 30-32% of the Home Areas (both for Total Fishes and Bottom Fishes), a certain level of maturity has been reached decade ago or more and landings have been maintained on average, often with medium term fluctuations. This situation may also reflect different realities:

a) **Sustainability.** The governance system has managed to develop a fishery system, the level of which is commensurate with the resources available. Considering the state of world fisheries, this would be quite an achievement. The hypothesis would become particularly plausible if the country concerned had put in place, early in its development, effective restrictions to access and fishing capacity.

b) **Economic constraints.** The fishery sector of the country constrained in its development (despite the non-limiting abundance of resources) because of lack of market, technology or financial resources. Considering the level of globalization of fisheries, and the long-term availability of technical and financial assistance for developing countries for at least three decades, this hypothesis is probably not the most likely.

c) **Sequential overfishing.** This has been described many times (cf. section 4.3). It may be possible to maintain for some time the level of landings obtained from a given area, by progressive replacement of declining resources by new ones previously underexploited. The latter might have been present in the area, but not targeted at because of its low economic value or inaccessibility (for lack of the proper technology, or insufficient action rage of the fleet within the FAO Main Fishing Area. A very likely phenomena, observed in many Home Areas, is that, within the Total Landings examined here, the reduction of the Bottom Fishes resource base is masked by the growing production of the Small Pelagic Fishes. The potential for sequential overfishing is very high and could be checked by looking more closely at species the composition of the Bottom Fishes landing category (within lr limits inherent to the FAO database).

While under this pattern, senescence may not have started yet or may be insufficiently characterized, it could be behind the corner if the instruments to effectively control capacity are not in place, eventually
looking for development in other dimensions of the sector. Considering the real difficulty encountered in reducing capacity, the temptation might be high to look for solutions such as aquaculture and value added products (e.g. to maintain or increase the value of the production even if the latter stagnates or decreases). While these might be good development avenues in well managed fisheries, they are more likely to be additional sources of rent drain in unmanaged systems, leaving them on their trajectory towards characterized senescence.

About 30% of the Home Areas examined do not show any clear sign of decrease in their landing growth rate, i.e. they are still “developing”. This may reflect:

a) **Under-developed resources.** The growth process of the sector is still under way on a set of resources still exploited below their maximum productivity level. It would be important to put in place the needed development brakes to avoid overshooting the sustainable development targets.

b) **Sequential overfishing.** The traditional resources are being depleted but new resources are added at a faster rate. imply that these Home Areas are still in an active process of extension within the FAO Fishing Area, further offshore and deeper, possibly after having stretched traditional resources to their limit and beyond. In particular, the reaching of the end of the “developing” phase might be hidden by the sequential targetting (and possibly overfishing) of the Bottom Fishes and Small Pelagic Fishes categories (cf previous discussion under c) above).

However, a closer look at the individual Home Areas patterns shows that, while the simple polynomial function (2\textsuperscript{nd} order) fitted through smoothed landings may keep going up, the rates of increase, in a significant number of cases, are already very low (at about 1-2 % per year) which, by comparison with other areas, indicate that very limited additional growth might be possible, and only at high cost to the industry and society (if such developments are subsidized). For precautionary reasons, these cases should be probably considered as close to fully developed, requiring closer resource-by-resource assessments and new development policies and management strategies. The precautionary approach provided for in the FAO Code of Conduct and UN Fish Stocks Agreement has an important role to play here.

Considering these border “developing” cases as also requiring urgent analysis of the health of the sector leads to suspect that about 40% of the Home Areas are at or close to their maximum development potential and may be in need of urgent fishery reform. Among them, some are known to be already very actively testing and implementing solutions, such as New Zealand, Australia, Norway, Iceland, Canada, Chile and Peru. For the others, the movement towards reform is very slow at best. In many cases, assistance is needed to develop the collaborative process required to develop a consensual and credible plan to overhaul the sector.

The large number of graphs available for each category of resources (e.g. Total Fishes, Bottom Fishes) is so considerable that it not possible to attach them as annex to this report. However, following the process used in the regional representations, synoptic representations have been elaborated (**Figures 18 and 19**) for all Home Areas that have apparently reached maturity, in relation to Total Fishes and Bottom Fishes landings. The yearly landings were transformed in relative landings (dividing them by the Lmax value calculated for each Home Area in the decade of peak landings and zero long-term growth). Contrary to what was done for the regional synoptic views, no weighting was applied. At the bottom of each figure, there are a number of countries which have apparently not yet reached their maximum. The relative value could therefore not be calculated and the whole row was coloured in green, the colour retained for the “Developing” phase. The pictures reflects the fact that many countries’ fishery sectors apparently fell into senescence very early after WWII. It also shows the accelleration of global development in the 1970s and the fact that, during the last decade, a significant proportion of Home Areas have reached maturity.

For the regional synoptic representations (on Figure 16), the synoptic representations have been further elaborated to calculate, for every year, a percentage distribution of the stages of development observed across Home Areas (cf. section 3.2.4 for details), using for the representation the same RL categories and colour coding (**Figures 20**)
Figure 18: Total Fishes - Synoptic qualitative representation of the state of development of the assessed Home Areas. See text for the indicator used and the colour coding. Rows are ranked in relation to the decade in which the average maximum landing has been reached.
Figure 19: Bottom Fishes - Synoptic qualitative representation of the state of development of the assessed Home Areas. See text for the indicator used and the colour coding. Rows are ranked in relation to the decade in which the average maximum landing has been reached.
Figure 20: Total Fishes (top) and Bottom Fishes (bottom) - Percentages of the assessed Home Areas in the three main phases of the development cycle
Figures 16, and 20 (bottom), both related to Bottom Fishes represent indeed the same phenomenon. They both give a global picture of the development of this category of landings obtained from aggregating regional landings and national landings respectively. It would be interesting, again, to compare the development patterns of the Bottom Fishes and Total Fishes but comparing directly the two panels of Figures 20 is not easy. Figure 21 has been developed therefore to compare the evolution of the three development phases.

It can be seen that (1) the progression with time of the “Developing” phase is practically identical (the trend line is the bisector of the graph); (2) The “Senescent” phase progresses faster in the Bottom Fishes category, as one would have expected for fishes of higher commercial value; (3) by contrast the percentage of “Mature” Home Areas in Bottom Fishes stagnate around 20% as they become “Senescent” at a higher rate than Total Fishes.

Figure 21: Comparison of the evolutions shown in Figure 20 for Total Fishes and Bottom Fishes. For each year the % values for Developing, Mature and Senescent have been plotted against each other.
5. DISCUSSION

5.1. DATA ISSUES

The dataset can only reflect the imperfections of national information systems despite of the monitoring exerted by FAO, training programmes and occasional field checks during country-requested missions in the field. When obvious discrepancies pop up, they are formally reported to countries and clarification requested. Eventually, corrections are implemented. Because of the anomalies detected by FAO some years ago already, the data regarding China, for instance, are being checked in collaboration with the country and corrections will be made in a near future. Various problems potentially affecting the quantities reported and the detected trends:

a) Artisanal fisheries are often not properly covered by national statistical systems, particularly in remote areas. The raising factors used to calculate total landings from sampling data may not be updated often enough. The way auto-consumption is accounted for (or forgotten) is not always clear. Sport and recreational fisheries are often not covered.

b) It has been argued that, in areas with deficient fisheries governance or insufficient means, regular annual increases are “forced” in the reports to the governments and FAO in order to comply with the development plans;

c) Discards are not systematically reported. They have decreased from about 20 million tonnes in 1980-92 (Alverson et al. 1994) to about 7 million tonnes during 1992-2003 (Kelleher 2005), but their evolution since 1950 is unknown and a simple extrapolation of the two data points available to the entire time series, backwards and forward, would be extremely crude.

d) Following the EEZ claims, illegal fishing by traditional and new long range fleets is understood to have increased. Illegal catches may not be included in Fishstat, or may be misreported, for example attributed to another FAO Area, e.g. the Home Area where the catching vessel is flagged or an area to an area where the flag state had a fisheries access agreement. The extent to which this might have affected national catch declarations to FAO is not known for sure despite recent efforts to puts some numbers on this otherwise opaque phenomena (Pitcher et al. 2002; MRAG 2005; HTSF 2006; Tinch et al. 2008).

e) The portion of the total catch reported as “unidentified” may have changed with time, with changes in discarding practices and trade opportunities for the lower value species.

There may also be problems with the species composition. The amount (and proportion) of the landings reported as “unidentified” have increased from approximately 1 million tonnes (about 7%) in 1950 to about 10 million tonnes (close to 12%) in the last decade. The factors leading to increase or decrease of the amount reported as “unidentified” may have changed with time and include:

a) Factors of increase: (i) the general degradation of the resources leads to lumping together fish that, if bigger, would have their own market (the Mediterranean “soup fish” syndrome; the Asian “trash fish” syndrome). (ii) increased contribution of artisanal fisheries which tend to be less well identified; (iii) a new market has emerged for low-value or no-value species previously discarded (e.g. in aquaculture feeds).

b) Factors of decrease: (i) a new market develops for previously low-value species, requiring improved identification. (ii) a new regulation prohibits the landing of small sizes, promoting larger discards.

These potential errors, the detail and extent of which remain unknown, cannot be corrected “from outside” and have therefore been disregarded. It is assumed that such errors do not distort the patterns to the point of making them misleading at the large scale at which they are examined. In addition, the

15 The results obtained for this country and region will therefore have to be taken as provisional.
approach used in this study is considered as providing only a first “rough” diagnostic, partly validated through coherence with patterns in neighbouring countries and in the whole region.

It is cautioned that the results be taken as indicative and it is strongly recommended that the conclusions be tested at country level, using the national (possibly more detailed and robust) statistical records, with more contextual information, and in close collaboration with the experts in that country and with the industry itself.

5.2. **EMPIRICAL REFERENCE VALUES**

Albeit qualitatively, this study uses simultaneously two reference levels: (i) the maximum reported landings during the period when the long-term trend in growth rates oscillates around zero, and (ii) the zero-growth level itself.

### 5.2.1. Maximum reported landings

The maximum landing (Lmax) used to generate the synoptic view in Figures 14 and 15 is calculated within the 10 consecutive landing values in the decade where the long-term trend in growth hits the zero-growth line (and, obviously, landings are maximum, on average). It is assumed that, having reached this point, the likelihood to detect important new resources of the conventional type in the Home or regional area and to obtain any significant increase in landings is very slim or nil. We do not, however, equate this maximum with the aggregate theoretical Maximum Sustainable Yield of either the Home Area or the FAO Area for the following reasons.

- **a) The Home area maximum is partial:** It corresponds only to a part of the total potential of the area. It only reflects a saturation point in the relations between the bordering country and the resources of its Home Area.

- **b) The Home Area maximum is only one among others**

The asymptote value towards which a trend is heading or around which the fisheries landings oscillate at present, for a given Home Area, is only one of the many maximums that could have been reached in this Home Area, with different fishing and management regimes and a different long-term climate background. It is therefore an empirically realized maximum, reflecting historical patterns with higher weights for the more recent time intervals and events. It reflects the high point of a coastal country development trajectory and it is different from the ideal maximum that the conventional MSY represents. It may be closer to the “multispecies MSY” we might have calculated having at hand a reliable model capable of handling so many species and fisheries simultaneously. This is not the case and this calculated MSY would, in any case, be as “virtual” as the conventional MSY, stained by assumptions of homogeneity, equilibrium and reversibility. This does not deny the value of the global MSY calculated in the conventional manner for providing guidance to managers.

- **c) A “focus imaginarius” (sensu Kant)**

When calculated on fisheries or for Home Areas that have not yet reached and passed their maximum (i.e. the only time when such information has any strategic value), the calculated multispecies MSY should be considered as focus imaginarius (sensu Kant), i.e. an idea, an ideal, that is unreachable in practice but that can be agreed and used to focus energies towards that ideal. It is recognized that the empirical maximum observed could be transient, both in quantity and quality, affecting its economic and social value. But it can still be used as a starting point, indeed a reference point, when considering the urgent measures that might be needed nationally or at ecosystem level, to improve it, in quantity, value, or ecological content.

In case the maximum has not yet been reached, and provided some trend is clearly perceptible (i.e. the system has clearly reacted to fishing) we would dare to extrapolate that trend to get a first rough estimate of the level of production the sector might reach under the prevailing conditions, taking account of the high variability, and indeed adjusting regularly the extrapolation as new data come in.

In case the maximum had been clearly passed years or decades ago, (i.e. in the senescence phase), it must be remembered that the historical trends reflect trajectories resulting from the interaction of
complex and changing forces and the biological, ecological, or socio-economic impacts may not be easily reversible. In particular, when the historical maximum has been passed, there can be no certainty that it could be “recovered” exactly, whether in terms of quantities or species composition. Measures might be taken, nonetheless, to improve either the national fishing sector efficiency (if that was the issue) or the management of the resources, or both. Again, the clue should come from a closer examination of more data, at local level, particularly about the past development strategy, or the size of species at the market, and the final interpretations should involve the local scientists and the industry. In any case, a strict “return to the past” should not be taken as granted.

d) Relation between the Home Area and FAO Area maximums

One can refer here to Figure 6. It is clear that the relations between the empirical maximum obtained in each Home Area and that of the FAO Area as a whole cannot be generally defined. The empirical maximum for the FAO area is better defined pooling all the landings in the area, from the coastal countries as well as the non coastal ones. This is what was done in this study when looking at the World or regional situations.

In this study, Home Areas maxima were not calculated as the focus was put on determining whether or not countries had reached their empirical potential (and when) and in particular, what was the “present” situation (i.e. the situation in the last decade) and what might be the needs for change in policy, e.g. from an implicit expansionist laissez-faire to good governance and effective management. However, the empirical maximum average landing (during the decade when the long-term trend in growth rates reaches zero) can be used as a reference value of the maximum possible production under the prevailing level of productivity and socio-economic conditions.

The pattern shown in a Home Area is, to some extent, symptomatic of the overall situation in that FAO Fishing Area. Protracted stagnating or negative rates of increase in national fleets’ landings would indicate either that the resources in the FAO Area are declining or that the sector’s marginal efficiency (i.e. its capacity to grow) is stabilized or decreasing. The resources may be decreasing under the total fishing pressure in the area. It may also be that the national fishery has become ineffective (e.g. because of ageing, lack of maintenance, lack of replacement funding, lack of competitiveness with other fleets, etc.) or both. In both case, remedial action is needed, reducing national capacity, re-negotiating sharing agreements when appropriate, exerting pressure on the relevant RFMO to improve management, etc. It has been argued that, in some cases, landings may decrease because of voluntary catch restrictions. They are extremely rare in the long run and can easily be verified at country level.

The important point is that one would have to look for arguments to prove that the concerning trends observed have nothing to do with the resource depletion, shifting the burden of proof to the government and the industry who have provided the statistics in the first place.

The systematic separation of the landings in “Bottom Fishes” and “Small Pelagic Fishes” is advisable as it provides improved resolution in the analysis and one would expect that these fisheries would have followed and reached different trajectories, in terms of quantities landed (pelagics are usually more abundant), variability (pelagics are more variable) and timing (high value bottom fish have usually reached their asymptote earlier).

5.2.2. The relative rate of increase

The trend in ROI is central to the diagnostic, particularly when the maximum average reported landing has not yet been reached. The more clearly “logistic” (i.e. S-shaped) the left part of the development pattern, the easier it is to detect the trend of the ROI towards zero. This implies a strong acceleration at the initial stages of the development phase. The ROI may reach the zero value (and even negative values) many time during the development cycle if there are strong fluctuations in the process, of natural or socio-economic origin. However, the amplitude of these oscillations appears to decrease as the maximum is approached. The reason for the reduced amplitude may be that: (i) large stocks are discovered and exploited fist; (ii) expansion occurs from coastal to offshore areas along a decreasing gradient of biomass and productivity. In the long term, both factors progressively reduce the
probability that large untapped resources be discovered, inducing the characteristic flattening of the landings curve with time.

5.3. THE NATURE OF FLUCTUATIONS

The analysis is complicated by fluctuations. Growth is not constant and fishery data are far from perfect. As a consequence all the graphs elaborated at global, regional and Home Area level show fluctuations at various frequencies, the amplitude of which is amplified by the use of ratios and probably by the smoothing process (at least for periods equivalent to the smoothing interval: 5 years). Their analysis is complicated by the existence of a strong trend and a strong increase of the variability at low landing levels, usually but not only during the early years. The fluctuations tend be more erratic in small island countries as well as in countries with turbulent history, e.g. where the development pattern has been disturbed by civil or independence wars, political restructuring (e.g. USSR), etc.

The medium-term to long-term fluctuations might reflect resource outbursts of climatic origin (Klyashtorin 2001; Lehodey et al. 2006) or related to major technological developments. The total world landings patterns, for example, are clearly affected by the natural fluctuations of the five major pelagic or semi-pelagic species: anchoveta, Alaska pollock, Chilean Jack mackerel, South American and Japanese and pilchard (Garcia and Newton 1997). However, these fluctuations also signal (and trigger) industrial developments, e.g. in the fishmeal and the surimi industries. They could also signal major geographical expansions of important fisheries.

The shorter term fluctuations (from one to 3 years), present in all series, may reflect a background “noise”. A number of series seem to contain medium-term fluctuations -of about a decade. An illustration is provided by Tanzania (Figure 22) or Egypt (Figure 23, left). In addition, both side of the Indian Ocean (Figure 23 right) seem affected by oscillations of about 2 decades. These figures illustrate the fact that the fluctuations become more conspicuous after smoothing. Having used a running average on 5 values, oscillations with that periodicity should be considered spurious unless clearly visible in the raw data.

5.4. PATTERN SIMILARITIES

In the diagnostic process, some strong similarities have been sometimes noted between patterns even though no systematic attempt was made to compare them. Some useful comparisons come to mind, however, that may be worth pursuing in a more comprehensive analysis.

5.4.1. Egypt

A striking pattern similarity has been noted between the two Home Areas exploited by Egypt: the East Mediterranean and the Red Sea (Figure 23, left). The volumes of landings are different but the evolutions are practically identical, both in terms of landings and growth rates. This raises a few issues:

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16 The term “oscillations” is avoided as the extent to which these fluctuations were periodic has not been studied yet.
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Figure 22: Tanzania-Total landings and ROI. Example of apparent oscillations. Trends in ROI are materialized with a simple polynomial (second order).

Figure 23: Pattern similarities. Right: Between western (51) and eastern (57) Indian Ocean areas-Bottom Fishes. Left: Between the Egyptian Mediterranean (37) and Red Sea (51) Home Areas-Total Landings.
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a) If the apparent medium-term oscillations (about 10 years apart) were spuriously generated by the smoothing process, the probability that these two patterns, belonging to the same country, are that similar just by chance must be extremely low;

b) If the oscillations are real and the drivers were natural, it would imply that there are common regional forcing mechanisms for these ecosystems a priori different;

c) If the oscillations are real, and the drivers are socio-economic, they could be related to national development plans and the duration (10 years) and the timing should match. This has not been checked.

d) Some readers may argue that these statistics may have been coherently and patiently forged, during half a century, by complacent staff dealing with both areas. While this cannot be excluded in the case of a single country, the next example, however, implies that other explanations may be likely.

5.4.2. The Indian Ocean

In the Indian Ocean, it has also been noted that the trajectories of landings and growth rates were strikingly similar (Figure 23, right). Considering the distances involved and the differences in the ecology, socio-economic and political conditions, these ocean-wide similarities are puzzling. The probability that they result from pure coincidence would seem rather slim. A number of possible explanations come to mind:

a) A large-scale climatic phenomena (with a periodicity of about 20 years?) is at play across the whole Indian Ocean area;

b) Large scale political events have shaped the area, e.g.: (i) post-WWII colonial developments (1950-1960); (ii) law of the sea extensions (1970-1980s) and perhaps related FAO-UNDP development programmes; and (iii) modern market globalization-driven expansion (1990-2000).

Whatever the explanation might be, the hypothesis we on touched on above, according to which complacent national staff of the numerous countries involved might have jointly forged this similarity during 50 years could not even be considered here. It would therefore seem that despite their alleged and objective defects, these landings statistics are still capable of reflecting coherent patterns.

5.5. PATTERN INTERPRETATION

The diagnostics given in this first stage report are to be considered as examples of the sort of conclusions that could be reached using available long term landing data. No hasty conclusions should be drawn from their superficial reading. The Belgium-27 Home Area, for example, has been in a deepening senescent trend for 5 decades or so. Does Belgium have irresponsible fisheries governance? Probably not. Belgium is not in a position to manage alone the resources of FAO Area 27 and its sector may have remained oriented on very conventional species, not diversifying targets, despite their progressive greater scarcity. It should be suspected that many of the Home Areas appearing as “developing” using Total Fishes landings as indicator owe this status to the progressive replacement of declining Bottom Fishes by Small Pelagic Fishes. This has indeed been verified in a sample number of Home Areas but the incomplete results could not be reported here.

Another example can be given in area 77 (cf Annex 6). In this area, the Total Landings appear as having reached a “Mature” phase about three decades ago and, since then, have oscillated without trend. The real significance of this situation, in terms of state of the various single fisheries or stocks in recent times is not easy to determine with only this data at hand. Hilborn (2007) describes this area (referring specifically to the California Current ecosystem) as one with a history of sequential depletion of important stocks, followed by partial but sometimes significant, recovery, where a number of small stocks (representing 1.5% of the total unfished biomass) are still overfished, but main resources are in good state and under-exploited because of constraining measures introduced to protect threatened but less abundant species. According to Hilborn, the area is one where abundance has been
significantly reduced by fishing, perhaps as much as 70% but one where important resources are close to MSY, where loss of yield by overfishing is limited (8%) and in which landings of some key species are well below historical levels only because of market conditions, management rules, and natural fluctuations. The situation is obviously complex and might be appreciated differently by different analysts. It underlines the fact, however, that an apparent state of “maturity” may hide different levels of “tension” on the various components of the resource, including landings restrictions related to markets or management.

The conclusions given in this report need therefore to be refined in many ways, including:

a) **Separating Bottom Fishes and Small Pelagic Fishes from the Total Fishes.**

This is a first priority. The trends are likely to be different and to present a worse situation for Bottom Fishes than for Small Pelagic Fishes, aggravating the overall diagnostic made on Total Fishes. **Figure 24** shows example based on Netherlands ([Figure 24 left](#)) and Norway ([Figure 24 right](#)). The separation of the categories shows the differences in trends. It confirms that the Small Pelagic Fishes tend to influence the overall sector landings more then the Bottom Fishes. The separate treatment of the categories ([Figures 25 and 26](#)) clarifies the component patterns.

In Netherlands, the Total Fishes trajectory shows two levels of rather stable landings separated by a sharp increase. The ROI trend is flat around zero except during that period. The phase graph reflects this pattern. The separation of two main components improves the understanding. Bottom Fishes developed in 1960-1979 and oscillate since then. Small Pelagic Fishes production collapsed in 1960-1979 and recovered later on, oscillating without trend since 1980. The data series does not cover the very early stages (undeveloped and fast growing), reducing the contrast. In addition, the combination of the two main resources (with the other minor components) in Total Fishes, give a correct view of the total sector trajectory, but cannot be properly interpreted without getting into the details.

In Norway, Total Fishes have been oscillating around 2.5 million tonnes for more than 4 decades. However, the separation shows that with oscillations in both cases, Bottom Fishes have kept increasing for decades while Small Pelagic Fishes have decreased during the same period.

**Figure 24:** Trends in Total Fishes (Blue), Bottom Fishes (Pink) and Small Pelagic Fishes (red) in Home areas Netherlands-27 and Norway-27
In both cases, the diagnostic is not crystal clear. It must be stressed that the methodology suggested in this report is not for prime use by the most developed countries, for which the early development data are not available (in the FAO database at least) and in which sophisticated fishery science has been active for decades if not centuries. At best, the systematic use of aggregated data of the type used here might provide some coherent fisheries development frame in which to nest the conventional and sometimes piecemeal stock assessments, too often disconnected from overall development trends. The approach proposed would be more useful in developing countries, where early data is more likely available (albeit sometimes of a questionable precision) and sophisticated fishery science is scarce or inexistent. In these cases, combining this approach, single assessment when available, and stakeholders’ knowledge might improve understanding and consensus, improving the basis for action.

b) Refining the landings trend line.

In this report, a running average has been used to enhance the trend, and a simple second order polynomial has been used to characterize the entire period. It must be stressed that the polynomial was used simply as a visual guide and not for any calculations. In many cases, however, this polynomial misses important features of the trajectory. For finer analysis, a higher order polynomial may be preferable, particularly if a statistical forecast is attempted. Figure 25 gives an example.

c) Refining the growth rate trend line.

The running average is particularly useful in improving the trend visualisation. However, the simple polynomial fit, used only as a visual guide) is particularly poor for the growth rate since its long term trend follows a non monotonous complex trajectory. In the fast growth to maturity process, the trend is quasi linear and a linear or curvilinear regression could be used, particularly if a forecast is attempted (e.g. when maturity has not yet been reached).

d) Identifying “anomalous” patterns.

While, in general, a paraboloidal or pseudo-Gaussian landing pattern is expected (for the entire development cycle), it could be deformed by strong climatic oscillations, major changes in fisheries development strategies and/or socio-political perturbations. This problem has impeded the assessment of about 21% of the time series which were incomplete, shortened, “abnormal” (cf Table 1) or showing no trend (indeterminate pattern). Their analysis requires more in-depth analysis with more data at hand. Figure 25 (top left) gives one example of anomalous pattern.
6. CONCLUSIONS

Observation of the long-term trends in landings and rates of growth has led to identifying patterns of increase, stability and decrease. These patterns are elements (or phases) of an empirical fishery development cycle. With some modifications, and taking account of natural and other oscillations, this development cycle (usually accepted for single fisheries) has been shown to apply also to the species aggregations selected for this study. The different phases identified have been used to establish a diagnostic about the state of development of the fishery sectors at global regional and national level. Though not comparable to a conventional stock assessment, this diagnostic provides some insights about the state of the underlying resources. These could be improved by further refinements of the approach as indicated in the discussion. The following conclusions are therefore provisional.

At world level, the landings of fin fishes have stabilized since the mid 1980s (for the Bottom Fishes category) and the mid 1990s (for the Small Pelagic Fishes category). The Other Marine Fishes, the unidentified component of the conventional landings, have also stabilized since the mid 1990s. However, landings of crustaceans and particularly cephalopods have continued to increase, reflecting likely shifts in fishing practices as well as ecological balance. This confirms that, at global level, many conventional resources appear to have reached their maturity, i.e. their maximum production under the prevailing mix of fishing and management regimes and environmental conditions. The “maturity” diagnostic hides serious ecological changes and contributes to socio-economic tensions.

At regional level, considering all resources categories together (Total Fishes), Areas 21 (NW Atlantic) and 47 (SE Atlantic) appear to have been in a senescent phase for decades. Many areas have reached their maximum production during the last quarter of the last century (since 1975) and have given signs of senescence during the last decade or more: Areas 21 (NE Atlantic), 31 (EC Atlantic, Gulf of Mexico), 37 (WC Atlantic, Mediterranean and Black Sea), 61 (NW Pacific) and 81 (SW Pacific). A number of Areas seem to have reached their maximum more recently and do not show yet any sign of decline: Areas 41 (SW Atlantic), 51 (Western Indian Ocean), 67 (NE Pacific), 77 (EC Pacific) and probably 87 (SE Pacific). Two areas do not show yet any maximum: Area 57 (Eastern Indian Ocean) and 71 (WC Pacific). A synoptic representation of these results indicates that the early development phases have ended soon after WWII in the Northern Atlantic and between 1960 and 1990 in the rest of the world. The analysis of the Bottom Fishes at regional level shows a generally similar pattern (with some differences in the position of the different regions along the general trend but, most importantly, shows that, as expected, the situation of the Bottom Fishes is worse than that of the Total Fishes, stressing the need to disaggregate the total landings by main category (at least) in order to make a more specific and relevant diagnosis.

At national level, this preliminary analysis has only considered the trends in Total Fishes and Bottom Fishes (selected) landings and growth rates. Of the 224 Home Areas analysed, between 107 and 169 (79 and 48% respectively) could be interpreted. Within these, the following development patterns were observed (Total Fishes and Bottom Fishes respectively): Developing (30.7 and 22.4%), Mature (30.2 and 31.8%) and Senescent (39 and 40.6%). A closer examination of the “Developing” category showed that a significant proportion of these were apparently very close to maturity as shown by their very small growth rates.

Synoptic representations of the state of development of all assessed Home Areas have illustrated the global historical development of these areas in terms of Total Fishes and Bottom Fishes, confirming the more depressed state of the latter.

17 The diagnostic for Area 61 is significantly influenced by the Chinese statistics and should be revised when these are updated.
Figure 25: Netherlands. Total Fishes, Bottom Fishes and Small Pelagic Fishes. An example of clarification obtained by separating the main resources categories. The trend lines (left column) are polynomials of 4th order.
Figure 26: Norway. Total Fishes, Bottom Fishes and Small Pelagic Fishes. An example of clarification obtained by separating the main resources categories. The trend lines (left column) are polynomials of 1st order.

All the countries responsible for the Home Areas concerned appear to need a careful look at the state of their fisheries:

a) For Home Areas that appear to be still developing but with residual growth rates and Areas that have reached maturity recently, the countries concerned need to have in place the mechanisms to stop the growth in fishing capacity and to control removals, in order to avoid the usual and costly “overshooting” of the maturity stage (i.e. entering the senescence phase simply because of the inertia of the sector as it adjusts itself to growing depletion).

b) For Home Areas that have reached maturity many years ago and apparently were able to sustain the fishery production at mature level, the countries need to check that the apparent sustainability is not hiding sequential overfishing, maintaining production at the cost of
changes in species composition and loss in the unit price. These countries also need to ensure that they have in place the mechanisms to avoid or reduce fishing overcapacity. In case the stable production would reflect not maturity but stagnation (due to lack of inputs or markets) incentives, development incentives would be needed.

c) For Home Areas that have declined to a senescent phase, the countries need to devote serious attention to the state of their fisheries which, in most cases, will be suffering from degradation of the resource base beyond the ecosystem capacity to adapt itself to the growing fishing pressure. In these cases, comprehensive sector reform and investment in affordable capacity-reduction programmes is likely to be needed.

d) It cannot be overstated that the diagnostic presented for each Home Area is only preliminary. It should be repeated with the same methodology but separating Bottom Fishes from Small Pelagic Fishes. The expected result of that step is likely to be an aggravation of the diagnostic for bottom fish fisheries and an improvement in the case of small pelagic fisheries. The next step could be a closer examination of the trends in “Other fishes” attempting, at national level, to reallocate the landings to the two main categories. This step is not expected, however, to change the preceding diagnostic. The next step would be to assess separately at the various fisheries and resources or group of resources, nesting them in the broader aggregated diagnostics.

Even at this stage, however, the analysis reflects a situation similar to that described by FAO regarding the state of the world resources with 25% of resources still developing, 50% fully exploited and 25% having more or less severe levels of overexploitation. This similarity reinforces the view that this preliminary analysis, based on a long time series of publicly available data, and a simple methodology, provides a first panorama of the situation at global, regional and, in particular, national level. It is therefore hoped that this report (which will be finalized with more complete analyses in the coming months) can serve as a basis to open dialogue between the World Bank and its members on the ways and means to improve further the diagnosis and to intervene to reform the sector where appropriate.

This analysis underscores also the importance of good fishery statistics as indicators of the sector and fisheries trajectories. It is clear that this analysis, as well as more conventional stock assessment, at national or regional levels, are impaired by the insufficient quality of the data and that efforts should be made to improve them. A major improvement would be in separating the fishery data between the areas under jurisdiction and the high seas. Another is to improve the identification in order to improve the conventional assessment but also to understand better the impact of fisheries on biodiversity.
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PRELIMINARY REPORT (Version 2)


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ANNEX 1 - A SHORT HISTORY OF THE WORLD FISHERIES POTENTIAL ESTIMATES

In the early 1970s, in a period of rapid expansion of world fisheries, John Gulland, at the time head of the Marine Resources Service of FAO, assisted by numerous fishery resources specialists from all over the world, published the most cited review of the state of world fisheries and of their global potential for conventional resources: about 100 million tonnes per year (Gulland 1971). Many attempts had been made before him to estimate, in various ways, at how much the world fisheries development could hope to produce. Pauly (1996) has compiled a short summary of the numerous attempts made by Graham and Edwards in 1962 (55 and 115 million tonnes); Schaefer in 1965 (200 million tonnes); Ryther, in 1969 (100 million tonnes); Gulland in 1971 (80-100 million tonnes); Idyll 1978 (100-120 million tonnes); and Moiseev in 1992 (120-150 million tonnes).

These attempts were based on fisheries harvest (extrapolation of catch trends, quantities harvested per unit of area, primary production and transfer efficiencies, including transfer to fisheries, that were soon after criticized (Gulland 1971). Pauly (1996) reviewed some of the critiques and also critically examined the assumptions made by Gulland, in particular the share of the exploitable biomass that might be safely harvested in the long term. The early estimates based on primary productivity have generally produced larger estimates of the potential. Those based on fisheries harvest data, not too surprisingly, have given estimates more closely related to the harvest data from which they were extracted.

Other estimates have been made. An earlier estimate of Moiseev (1973) estimated the world potential of about 82 million tonnes. Robinson (1980) forecasted a maximum world harvest of 77-88 million tonnes. He also recognized that small pelagic species were still offering considerable opportunities of catch increases (also in shellfishes such as cephalopods and crustaceans). He also recognized that there was a substantial excess capacity (in long distance fishing) that would probably not be redeployed to satisfy the needs of new independent countries (predicting indeed the build-up of the present global overcapacity). He also correctly predicted substantial changes in trade patterns following the “closure” of EEZs (faster increase in quantities traded than of quantities produced).

Recognizing explicitly the limitations of the data as well as the problems of applying the production model theory to an aggregated world stock, Garcia and Newton (1997), for the first time perhaps, used both the world harvest and global fleet size index (the world fleet gross tonnage), at the extreme limit of the conditions for application of the Fox production model, to assess the world potential and the state of fisheries. They considered world fisheries as a single globalized process of exploitation of a mosaic of resources by a mosaic of fisheries in order to assess the order of magnitude of the world fishery problem in both biological and economic terms. They concluded that the potential was about 60 million tonnes (without the 5 most highly variable species) and about 83 million tonnes for the total landings. The less variable species appeared overfished with a 30% overcapacity. The whole stock appeared fully exploited. Using largely the same cost and earnings data as Francis Christy (FAO 1993) they confirmed the order of magnitude of the likely financial losses of fisheries during the early 1990s (about 46 billion dollars) with an overcapacity of about 25-53% depending on the selected reference points.

The above indicate that more than 3 decades ago, the potential of the world potential was pretty well known (or guessed, if one considers all the assumptions) and even the order of magnitude of the regional potentials were also known. For example, the correlation between Moiseev (1973) estimates of the potentials production of FAO areas and the historical average peaks of production in these

18 Anchoveta, Alaska Pollock, Chilean jack mackerel, South American pilchard and Japanese pilchard.

19 Calculated as the average of the 5 highest values in a series of 10 contiguous values in the area of the overall maximum (the area of the historical maximum of production)
areas is relatively good (R=0.83 for 13 values) if the North Pacific (areas 61 and 67 together), seriously underestimated by Moiseev, are put aside.

However, the remaining uncertainty was still too high to discourage investments and, as history has demonstrated, governments and industries do not make decisions based on global or regional estimates of potential, no matter how precise these might be.

Very recently, Jennings et al. (2008)\textsuperscript{20} combined remote sensing data (primary production and SST) with a global-scale biomass conversion model, and provided regionalized estimates of potential marine animal biomass and production by body mass class. The estimated world production of teleost fish of 10g wet weight and upwards amounts to 110 million tonnes/year and the reported fish landings from the four major FAO areas (in terms of volume of the landings) are very close to their estimated fish production potentials. This convergence between conventional fisheries assessments and assessments based on ecosystems productivity may confirm that, globally, and by region, the present landings are close to the biological potential. The same applies probably to countries where the long-term trend in the rate of increase has been zero or negative for some time.

ANNEX 2 - THE FISHERY DEVELOPMENT MODEL

Business development “cycles”

Since the 18th century, the oscillations affecting business development have been noted and discussed e.g. by Malthus (1766-1834), Ricardo (1772-1823) or Marx (1818-1883) (R. Arnason, pers. Comm.). In 1860, the French Economist Clement Juglar (1819-1905) described them dividing them into 4 phases: expansion, crisis, recession and recovery. A comprehensive treatment of the subject was given by Schumpeter (1939). These fluctuations are still often referred to as business or economic “cycles” even though there was and still is controversy about their real nature. Are they entirely random? Are they provoked on an otherwise random fluctuation by “shocks” corresponding for example to changes in policy, credit availability, technological innovations, etc. Are some periodicities deterministic and predictable as believed by Kondratieff (1892-1938) and Marchetti (1987)? Independently of their nature and underlying mechanisms, there seem to be currently a common understanding among business development specialists that businesses develop with fluctuations of their economic activity (sometimes referred to as “booms and busts”) around their long term development trend. These involve shifts over time between: (i) an initiation phase of exploration and invention; (ii) a growth or prosperity phase showing a relatively rapid growth of investments and output; (iii) a phase of relative stagnation or decline during which the business experiences contraction and recession and, hopefully, (iv) a phase of recovery.

The single-fishery development cycle

Fluctuations are certainly a central characteristic of fisheries resources and fisheries activities and they can be observed at stock, sector, region or global levels. At single fishery level, these phases have been identified: initial low production, followed by fast growth, fluctuating stagnation, and, sometimes, decline and collapse (Larkin and Wilimovsky 1973; Csirke and Sharp 1984). These may originate in government policy changes or private sector decisions to capture new opportunities. In addition fisheries resources and the outcome of fishing and management have clearly been affected by ocean-atmosphere coupled oscillations such as the El Niño Southern Oscillation (ENSO) in the equatorial Pacific, the North Atlantic Oscillation (Marshall et al. 2001, Stenseth et al. 2003, Wang & Fiedler 2006) as well as by the increase in the heat content of the world ocean (Levitus et al. 2000). Biological effects attributed to quasi periodic decadal-scale climatic fluctuations have been described, sometimes in synchrony across space and species, sometimes in phase opposition (Glantz and Thompson 1981; Csirke and Sharp 1984; Klyashtorin 1998, 2001, Chavez 2003). The latter appear sometimes in synchrony across space and species, and sometimes in phase opposition (Glantz and Thompson 1981; Csirke and Sharp 1984; Klyashtorin 1998, 2001; Chavez 2003). Furthermore, violent events such as civil and other wars send shocks through the entire economic system and disturb the “classical” logistic development pattern. Through delayed dynamics response of the stock and of industry, these perturbations have generated fluctuations in the outputs of the sector, in both quantity and quality. Klyashtorin has even used the cycles identified to predict catches and their species composition in the future. In analyzing fishery production trends, we should therefore expect to see, in the landings data, a general development pattern for the period 1950-2006, reflecting essentially investments in the production chain and increasing consumption. This long-term trend should be perturbed by higher frequency fluctuations reflecting co-generated by natural and socio-economic drivers as well as sampling noise.

The conventional single fishery development model or cycle (as described for instance by Csirke and Sharp 1984) can be decomposed in phases as follows:

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21 Marchetti (1987) has drawn attention on the existence of logistic growth patterns in number of economic and social fields such as energy consumption, the use of horsepower, the appearance of basic innovations and key scientific discoveries, bank failures, homicides, etc. These fields experience growth and declines as “epidemics” which, according to Marchetti, justifies the use of biological logistic models to describe and forecast such complex socioeconomic developments

22 For instance in the relative proportions of small pelagic and demersal fish.
I. Pre-development: also referred to as under-development or exploration phase is characterized by a very low fishing pressure, no or limited market, no or ill-adapted technology. Biomass is close to virgin levels. Catch rates bear little or no relation to those that a targeted fishery could obtain. Innovative fishers look for opportunities. The stocks are considered as “underexploited”.

II. Growth. Or development. It has sometimes been subdivided into: (i): an initial growth, involving only a few pioneers, innovators and risk takers, and (ii) a full or exponential growth when the innovation spreads rapidly to new entrants attracted by the high initial catch rates and profits. Growth can happen in a series of successive bursts separated by stabilization periods (Larkin and Wilimovski 1973). It is triggered by development clues such as discovery of a new resource, invention or adoption of more efficient gear or fishing practices, increasing boat range (through improved motorisation or catch preservation techniques), and opening of a new market. Specific infrastructures are developed and economic incentives provided that attract new entrants. The development brakes necessary to avoid “overshooting” are rarely put in place. The stocks are considered as “intensively exploited”.

III. Full exploitation. It is generally difficult to know when a fishery has reached full exploitation before that stage has been passed. In the Law of the Sea Convention, full exploitation meant extracting the Maximum Sustainable Yield (MSY). Since the adoption of the 1995 UN Fish Stocks Agreement, MSY is to be considered as a limit and not a target. Full exploitation should therefore stop before. During that phase, abundance decreases further. The less efficient operators may be forced out of the fishery. In multispecies fisheries, some may transfer part of their efforts to some bycatch or other species acceptable to the consumer, looking for new markets. The periods of stability are ultimately characterized by a dominating set of harvesting techniques. If they were well managed, stocks (and catch rates) would stabilize and only oscillate around their mean, driven by climatic conditions. Indeed, in the general business cycle, this should be the stabilization phase. In practice, this phase has tended to be ephemeral as the fishery moves into the next phase. The stocks are considered as “fully exploited”.

IV. Overexploitation. A phase apparently described only in fisheries although overdevelopment and overinvestment exist in the general business theory. The fishing pressure is higher that the level corresponding to MSY. The phase can be more or less rapidly depending on fishing pressure build-up and the species life parameters. Overexploitation (or overfishing) may happen while catches are still higher than MSY (“overshooting”) because of the delay in the stocks response to fishing. Eventually catches will decline (and catch rates plummet) as the stock finally adjusts to the pressure. When overexploitation meets with poor climatic conditions, the collapse can be fairly rapid. Under overexploitation regime, the stocks are (or soon become) “overfished”. When overexploitation is severe and biomass have been reduced well below the MSY level, the stocks are labelled as “depleted”.

V. Collapse. Originally, this term intended to describe a situation of sudden and deep decrease of abundance and catches, usually immediately followed by a sudden reduction of fishing effort as fishing becomes highly unprofitable. This usually happens when overexploitation meets with poor climatic conditions and leads important economic losses and intense social stress. The stocks are also considered depleted. It has been considered for a long time that excessive fishing could not extinguish target species. It is now recognized that some groups (e.g. the elasmobranchs) are at high risk. Recent work have shown that they might have led to extinction of local populations stocks (Dulvy et al 2004). Unfortunately, as those are not directly exploited, they may not be assessed and move “under the radar”.

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23 Annex II.7 of UN Fish Stocks Agreement provides that, “the fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points”.

24 Overdevelopment is a process by which natural resources are impacted by development at a rate significantly harmful to the ecosystem. Overinvestment is the practice of investing more into an asset than what that asset is worth on the open market (Wikipedia)

25 Examples include the Peruvian anchoveta and the Canadian cod.
VI. Recovery: hopefully, following the drastic reduction of fishing pressure (outright bans may be needed) and assisted by favourable climatic conditions, the stock may rebuild progressively its biomass, provide its habitat has not been strongly damaged (Francis et al. 2007). Many depleted stocks have been simply “left alone”, often still exploited as bycatch. In many other cases more or less formal recovery plans have been put in place with varying degrees of success (Caddy and Agnew 2004). The World Summit on Sustainable Development (WSSD) has adopted in 2002 a plan that foresees the recovery of the world depleted stocks by in 2015. The stocks are labelled as recovering.

Ideally, overfishing and collapse should only happen in unmanaged fisheries, with no or poor control on access to the fishery and extraction rates. In practice, overfishing is rampant and collapses happen not that rare, underlining the reform of fisheries development and management policies.
ANNEX 3 – PRODUCTION MODELLING IN COMPLEX FISHERY SYSTEMS

In fisheries science, the historical development of a fishery through its different development phases is often represented using the simple logistic biological production model (or surplus yield model) adapted to fisheries by Schaefer (1954). This model assumes a logistic saturation process of the ecological volume available to the resource—the so-called “carrying capacity” of its habitat. In other words, the intrinsic growth rate of the population tends to zero as the population size approaches the carrying capacity. From the onset of the population growth to the saturation of its habitat, the instantaneous variation of population size increases from zero to a maximum value, and then decreases to zero as the saturation is reached. In the logistic model, this self-limitation of population exponential growth by population size is described by a parabolic relationship (the Schaefer model), but many other “unimodal” curve types are suitable. This global model has been applied to fisheries by subtracting the instantaneous catch from the population production. It also assumes a parabolic relation between stock biomass and productivity or equilibrium catch. It assumes also a negative linear relation between fishing effort and abundance and a parabolic relation between catch and fishing effort. Recognizing that in real situations, the conditions required for a perfectly parabolic model were rarely fulfilled, various models allowing departures from the symmetric parabola were elaborated e.g. by Fox, Pella and Tomlinson, and many others. These variants allow more flat-topped representations to be used, reflecting a stronger resilience of the resources mix to exploitation than the one assumed by the Schaefer model. Even when dealing with a single stock and a single-gear fishery, the assumptions of homogeneity (of the stock and of the fleets), constancy of the relations (between effort and fishing mortality or between catch rates and abundance), equilibrium and reversibility of trajectories, implicit in the model, are rarely if ever fulfilled in reality.

In fisheries, the extension of the application of such models from single populations exploited by homogenous fisheries to multispecies multigear fisheries, emerged among biologists in management and scientific literature in the 1970s, in the Northern hemisphere (Garrod, 1973; Brown et al. 1976; National Research Council, 1977), and it has been of particular concern in the tropics where multispecies-multigear fisheries are the rule, both in marine and freshwater systems (Gulland, 1972; Henderson, Ryder and Kudhongania 1973; Pope 1979; Kirkwood 1984). An interesting historical record reflecting that concern can be found in FAO (1978), a report which is also a good source of references on early works in this area.

Both Gulland (1972) and FAO (1978) describe quite well the essence of the problem of applying a production model to a composite fishery, in relation to the Thai trawl fishery sector and particularly the problem caused by the geographical expansion of the fishery with time (changing underlying biomass and modifying fishery parameters) and the changes in species composition (due to the geographical expansion as well as changes in the ecosystem under fishing pressure. fishing intensity). While the fundamental relations structuring the production model probably still apply, the generality of the “pure” model is lost as the exact parameters of the relations, their shape, and the type of reaction one can expect from the system are unpredictable (Kirkwood, 1984). The few developments towards a new generation of production models for such situations (e.g. by Pope 1979) confirmed the need to use them and their conclusions with caution (Kirkwood, 1984; Holt 2009).

Nonetheless, for want of a better alternative, and assuming that, used with cautious they could still provide useful management guidance, these models have been used at aggregated level, for the assessment of multispecies resources in the tropics: in Thailand (Gulland 1972; Pope 1979; Boonyobol and Pramokchutima 1984); the Philippines (Dazell et al. 1987); Jamaica reefs (Munro 1978); African inland lakes (Henderson and Welcome 1974); tropical rivers (Welcomme 1976); East African marine fisheries (Gulland 1979); the Mediterranean (Garcia 1984); and the whole world (Garcia and Newton 1997; The World Bank 2008). It must be stressed that most of these applications were not intended for operational decision-making but as metaphors of the state of the fisheries or the
sector, as evidence that the resources were being significantly affected, and as support for strategic recommendations to exert stricter control on extraction rates; a foregone conclusion in many cases.

Kirkwood’s advice was to use them but empirically, conscious of the violations and possible consequences, not forcing the emerging relation to a convenient conventional form, particularly to the unlikely perfect parabola. Indeed, in inland fisheries (Welcomme 2001), it seems that the use of the multispecies production model has been more pragmatic and more realistic than in the marine fisheries, recognizing its no-parabolic shape and the numerous changes in the ecosystem as fishing stress increased.

This discussion is extremely relevant to our consideration of landings trends in this study. Like the aggregated fishery development model used in this study, the simple production model has been applied because of its limited data requirements. At the price, however, of a very limited explanatory and predictive power. Facing explicitly these difficulties when assessing the Gulf of Thailand fisheries, Gulland (1972) argued that “the surplus-yield model may be the only usable technique at present for the analysis of the complex fishery under study. It can establish the main dynamic properties of the fishery and can indicate the first steps required to regulate it for the management purposes which are urgently needed at present...reducing the total amount of fishing. Once this is done and the fishery as a whole is in a more healthy state, further analysis may show that additional management action may be needed, more specifically directed towards one or other species group. However, until this first step, to reduce overall effort, is taken...the combined analysis is perfectly adequate.

Gulland recognized the imperfection of the model and the resulting uncertainty. With the rigor and pragmatism that has always characterized his work, he suggested precautionary action: i.e. to cut down on effort as soon as possible (even if the scientific basis for the action was not perfect) and to follow with adaptive management. The situation Gulland faced in Thailand at that time is still the situation faced today in many developing countries, and not only there.

The global application of the bioeconomic production model by Garcia and Newton (1997) and more recently in the World Bank report (2009) to a global assessment of the State of fisheries, rest on the same rationale Gulland so nicely expressed 35 years ago, simply because the capacity to deal with the problem at that level of aggregation has not really improved. The urgency remains to reduce overall fishing pressure. The arguments brought about by these two studies despite their limitation _in addition to confirming stocks depletion_ is the huge amounts of wealth lost through subsidies and lost rents.

The application of the aggregated development model has been made with a similar rationale in mind.
ANNEX 4 - HOME FISHING AREAS CONSIDERED26

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</table>

26 For countries with multiple Home Areas, a totals has also been examined as a means to represent the evolution of the total fishing sector: Canada, Colombia, Egypt, France, Greenland, Guatemala, Honduras, India, Indonesia, Malaysia, Mexico, Panama, Thailand, .have also bee
### ANNEX 5 – SELECTED ISSCAAP CATEGORIES

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<th>ISSCAAP categories</th>
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<td><strong>1 Freshwater fishes</strong></td>
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<tr>
<td><strong>3 Marine fishes</strong></td>
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<tr>
<td>31 Flounders, halibuts, soles</td>
<td>Bottom fish</td>
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<tr>
<td>32 Cods, hakes, haddocks</td>
<td>Bottom fish</td>
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<tr>
<td>33 Miscellaneous coastal fishes</td>
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<td>34 Miscellaneous demersal fishes</td>
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<td>35 Herrings, sardines, anchovies</td>
<td>Small pelagics</td>
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<td>36 Tunas, bonitos, billfishes</td>
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<tr>
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<td>Small pelagics</td>
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<tr>
<td>39 Marine fishes not identified</td>
<td>Other fishes</td>
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<td><strong>4 Crustaceans</strong></td>
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<tr>
<td>41 Freshwater crustaceans</td>
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<td>42 Crabs, sea spiders</td>
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<tr>
<td>43 Lobsters, spiny rock lobsters</td>
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<tr>
<td>44 King crabs, squat lobsters</td>
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</tr>
<tr>
<td>45 Shrimps, prawns</td>
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<td>46 Krill, planktonic crustaceans</td>
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<tr>
<td>47 Miscellaneous marine crustaceans</td>
<td>Crustaceans</td>
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<tr>
<td><strong>5 Molluscs</strong></td>
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<tr>
<td>51 Freshwater molluscs</td>
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<tr>
<td>52 Abalones, winkles, conchs</td>
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</tr>
<tr>
<td>53 Oysters</td>
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<td>54 Mussels</td>
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</tr>
<tr>
<td>55 Scallops, pectens</td>
<td></td>
</tr>
<tr>
<td>56 Clams, cockles, arkshells</td>
<td></td>
</tr>
<tr>
<td>57 Squids, cuttlefish, octopuses</td>
<td>Cephalopods</td>
</tr>
<tr>
<td>58 Miscellaneous marine molluscs</td>
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<tr>
<td><strong>6 Whales, seals, other aquatic mammals</strong></td>
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<tr>
<td><strong>7 Miscellaneous aquatic animals</strong></td>
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</tr>
<tr>
<td><strong>8 Miscellaneous aquatic animal products</strong></td>
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<tr>
<td><strong>9 Aquatic plants</strong></td>
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</table>
ANNEX 6 - DEVELOPMENT PATTERNS IN FAO AREAS-TOTAL FISHES
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 34-Total

Area 37-Total

Area 41-Total

Landings (10³ t)

ROI (%)

Landings (10³ t)

ROI (%)

Landings (10³ t)

ROI (%)


0,0 500,0 1000,0 1500,0 2000,0

Developing

Mature

Senescent

Developing

Mature

Developing
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 47-Total

Area 51-Total

Area 57-Total
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 77-Total

Area 77-Total

Area 81 Total

Area 81-Total

Area 87-Total

Area 87-Total

Landings (10^3 t)

ROI (%)
ANNEX 7 – DEVELOPMENT PATTERNS IN FAO AREAS-BOTTOM FISHES
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 34-Bottom Fishes

Area 37-Bottom Fishes

Area 41-Bottom Fishes
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 47-Bottom Fishes

Area 47-Bottom Fishes

Area 51-Bottom Fishes

Area 51-Bottom Fishes

Area 57-Bottom Fishes

Area 57-Bottom Fishes
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.
PRELIMINARY REPORT

Area 61 - Bottom Fishes

Area 67 - Bottom Fishes

Area 71 - Bottom Fishes
Rising to Depletion? Towards a dialogue on the state of national marine fisheries.

PRELIMINARY REPORT

Area 77 - Bottom Fishes

Area 81 - Bottom Fishes

Area 87 - Bottom Fishes
## ANNEX 8 - DEVELOPMENT DIAGNOSTIC IN HOME AREAS. LAST DECADE

### Table 1: Total Fishes

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### Senescence 2

- Senescent 1

### Mature 51

### Developing 52

### Indeterminate 26

### Not assessed 20

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68
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**Legend:**
- **Senescent**: 6
- **Senescent 1**: 43
- **Mature**: 34
- **Developing**: 24
- **Indeterminate**: 23
- **Not assessed**: 94