controlling the production of cultured organisms from the sea.

See also

El Niño Southern Oscillation (ENSO). Fishery Management, Human Dimension. Mangroves. Mariculture Diseases and Health. Mariculture Overview. Salmonid Farming.

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MARINE FISHERY RESOURCES, GLOBAL STATE OF

S. M Garcia and I. De Leiva Moreno, Food and Agriculture Organization of the United Nations, Rome, Italy

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Introduction

The fisheries department of the Food and Agriculture Organization (FAO) monitors the state of world marine fishery resources and presents every two years to the FAO Committee on Fisheries (COFI) a report on The State of Fisheries and Aquaculture (SOFIA). This article draws significantly from a section of SOFIA 2000 on the state of world fisheries and uses the information available from 1974 to 1999 (the last year for which information is available).

With the view to offering a comprehensive description of the global state of world stocks, the analysis provided below considers successively: (1) the relation between 1998 and historical production levels; (2) the state of stocks, globally and by regions according to data collected up to 1999; and (3) the trends in state of stocks since 1974, globally and by region.

Relative Production Levels

The data available for 1998 for the 16 FAO statistical regions (**Table 1**) of the world's oceans indicate that four of them are at their maximum historical level of production: the Eastern Indian Ocean as well as the Northwest, Southwest and Western Central Pacific Oceans. All other regions are presently producing less than their historical maximum, for various reasons (**Figure 1**). Although this might result, at least in part, from natural oscillations in productivity (e.g., due to El Niño 1997 in the Southeast Pacific Ocean), the lowest values observed may indicate that a high proportion of the resources are overfished (e.g., in the Antarctic, as well as in the Southeast and Northwest Atlantic Oceans).

Global Levels of Exploitation

At the end of 1999, FAO had some information on 590 'stock' items. For 441 (or 75%) of them, there was some more-or-less recent information on the state. These 'stock' items are classified as underexploited (U), moderately exploited (M), fully exploited (F), over exploited (O), depleted (D), or recovering (R) depending on how far they are from 'full exploitation' in terms of biomass and fishing

Table 1 FAO statistical areas

In order to help organize its data FAO has broken down the world fishing areas into 'statistical areas'. These are identified by a two-digit number (21 to 88). In this article the numbers are replaced by acronyms.

ACW	Atlantic, Western Central (31)
AEC	Atlantic, Eastern Central (34)
ANE	Atlantic, Northeast (27)
ANT	Atlantic Total (48, 58, 88)
ANW	Atlantic, Northwest (21)
ASE	Atlantic, Southeast (47)
ASW	Atlantic Southwest (41)
IE	Indian Ocean, Eastern (57)
IW	Indian Ocean, Western (51)
MBS	Mediterranean and Black Sea (37)
PCW	Pacific, Western Central (71)
PEC	Pacific, Eastern Central (77)
PNE	Pacific, Northeast (67)
PNW	Pacific, Northwest (61)
PSE	Pacific, Southeast (87)
PSW	Pacific, Southwest (81)

pressure. 'Full exploitation' is used by FAO as loosely equivalent to the level corresponding to maximum sustainable yield (MSY) or maximum long-term average yield (MLTAY).

1. U and M stocks could yield higher catches under increased fishing pressure, but this does not imply any recommendation to increase fishing pressure.
2. F stocks are considered as being exploited close to their MSY or MLTAY and could be slightly under or above this level because of uncertainties in the data and in stock assessments. These stocks are in need of (and in some cases already have) effective control on fishing capacity.
3. O or D stocks are exploited beyond MSY or MLTAY levels and in need of effective strategies for capacity reduction and stock rebuilding.
4. R stocks are usually at very low abundance level compared to historical levels. Directed fishing pressure may have been reduced by management or because of a lack of profitability but may nevertheless still be under excessive fishing pressure. In some cases their indirect exploitation as by-catch in another fishery might be enough to keep them in a depressed state despite reduced direct fishing pressure.

Figure 2 shows that, according to information available in 1999, 4% of the world stocks appeared to be underexploited, 21% moderately exploited, 47% fully exploited, 18% overfished, 9% depleted and 1% recovering.

On the one hand, this indicates that 28% of the world stocks (O + D + R) for which some data are available are below the level of abundance corresponding to MSY or have a fishing capacity above this level. They require management to rebuild them at least to the level corresponding to MSY as provided by the 1992 UN Convention on the Law of the Sea (UNCLOS). As 47% of the stocks appear to be exploited around MSY and also require capacity control to avoid overcapacity, it appears that 75% (F + O + D + R) of the world stocks for which data

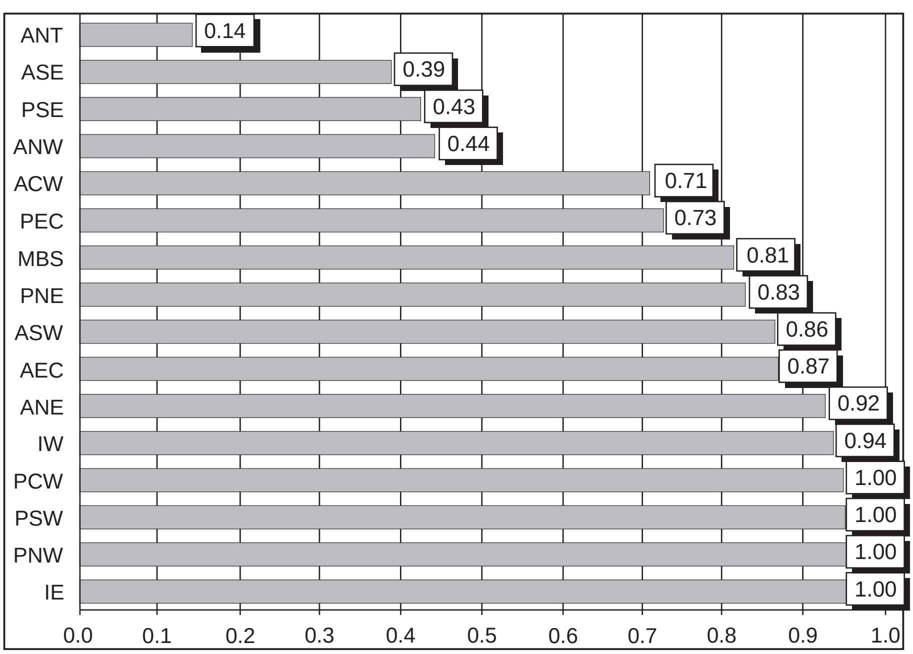

Figure 1 Ratio between recent (1998) and maximal production. For abbreviations see **Table 1**.

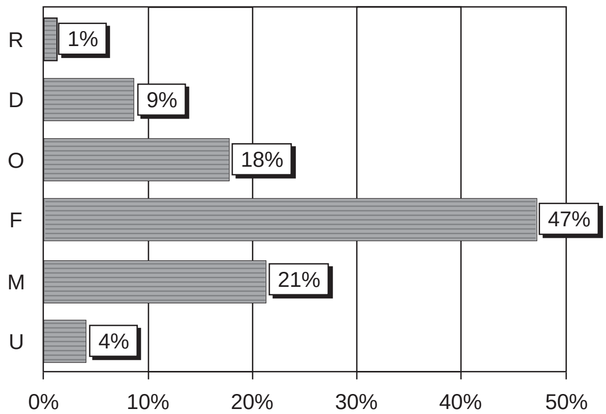

Figure 2 State of stocks in 1999. R, recovering; D, depleted; O, overfished; F, fully fished; M, moderately exploited; U, underexploited.

are available require strict capacity and effort control in order to be stabilized or rebuilt around the MSY biomass level, and possibly beyond. Some of them may already be under such management.

On the other hand, **Figure 2** also indicates that 25% (U + M) of the world stocks for which some data are available are above the level of abundance corresponding to MSY or have a fishing capacity below this level. Considering again that 47% of the stocks are exploited around MSY, this means that 72% of the stocks (U + M + F) are at or above MSY level of abundance with a fishing capacity below this level and should be therefore considered as compliant with UNCLOS basic requirements.

These two visions of the global situation of fishery stocks indicate that the 'glass is half full or half empty' and are equally correct depending on which angle one takes. From the 'state of stocks' point of view, it is comforting to see that 72% of the world resources are still in a state which could produce the MSY, as provided by UNCLOS. From the management point of view, it should certainly be noted that 75% of the resources require stringent management of fishing capacity. As mentioned above, some of these (mainly in a few developed countries) are already under some form of capacity management. Many, however, would require urgent action to stabilize or improve the situation. For 28% of them, energetic action is required for rebuilding.

State of Stocks by Region

When the available information is examined by regions, the percentage of stocks exploited at or beyond levels of exploitation corresponding to MSY and needing capacity control (F + O + D + R) ranges from 41% (for the Eastern Central Pacific) to 95% (in the Western Central Atlantic Ocean) (**Figure 3**). Overall, in most regions, 70% of the stocks at least

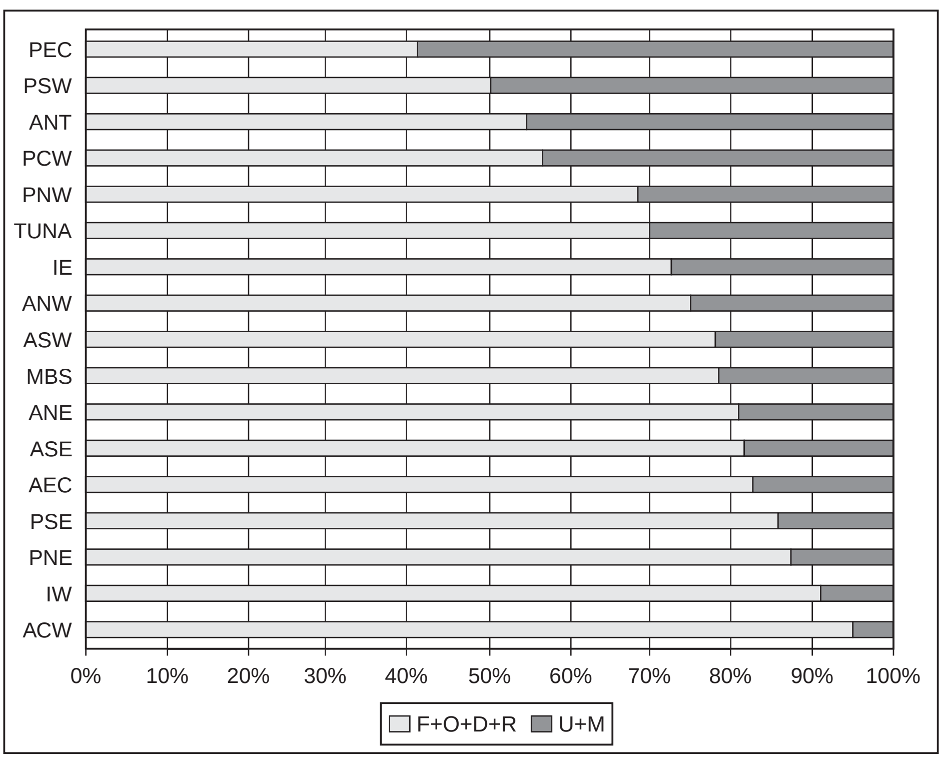

Figure 3 Percentage by FAO fishing areas of stocks exploited at or beyond MSY levels (F + O + D + R) and below MSY levels (U + M). For abbreviations see **Table 1**. TUNA, all tuna stocks for which data is available.

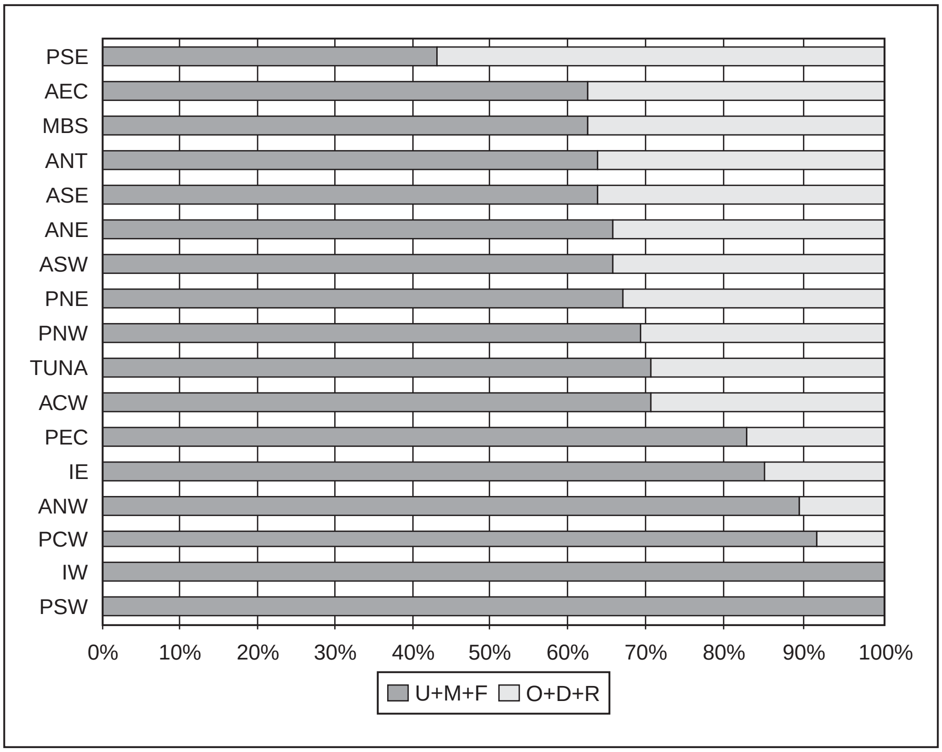

Figure 4 Percentage by FAO fishing areas of exploited at or below MSY levels (U + M + F) and beyond MSY levels (O + D + R). For abbreviations see **Table 1**. TUNA, all tuna stocks for which data is available.

are already fully fished or overfished. The percentage of stocks exploited at or below levels of exploitation corresponding to MSY levels (U + M + F) ranges from 43% (in the South-east Pacific Ocean) to 100% (Southwest Pacific and Western Indian Oceans) (**Figure 4**). As a measure of management and development performance, the proportion of stocks that are exploited beyond the MSY level of exploitation (O + D + R) ranges from 0% (Southwest Pacific and Western Indian Ocean) to 57% (the Southeast Pacific Ocean) (**Figure 4**).

Global Trends

The following analysis considers the trends in the proportion of stocks in the various states of exploitation described above. The years mentioned in the text and in the figures refer to the year of the publication of the FAO Circular *Review of the State of the World Fishery Resources; Marine Fisheries*. **Figure 5** shows that the percentage of stocks maintained at MSY level (F) has slightly decreased since 1974 whereas underexploited stocks (U + M), offering potential for expansion have decreased steadily. As would be expected from these trends, **Figure 5** also shows that the proportion of stocks exploited beyond MSY levels (O + D + R) has increased during the same period, from about 10% in the early 1970s to nearly 30% in the late 1990s. The number of 'stocks' for which information is available has also increased during the same period from 120 to 454.

Discussion

The perspective view of the state of world stocks obtained from the series of FAO biennial reviews indicates clearly a number of trends. Globally, between 1974 and 1999, there appears to be an

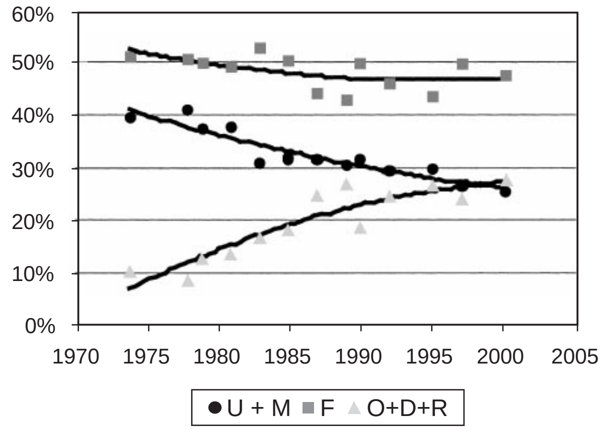

Figure 5 Global trends in the state of world stocks since 1974.

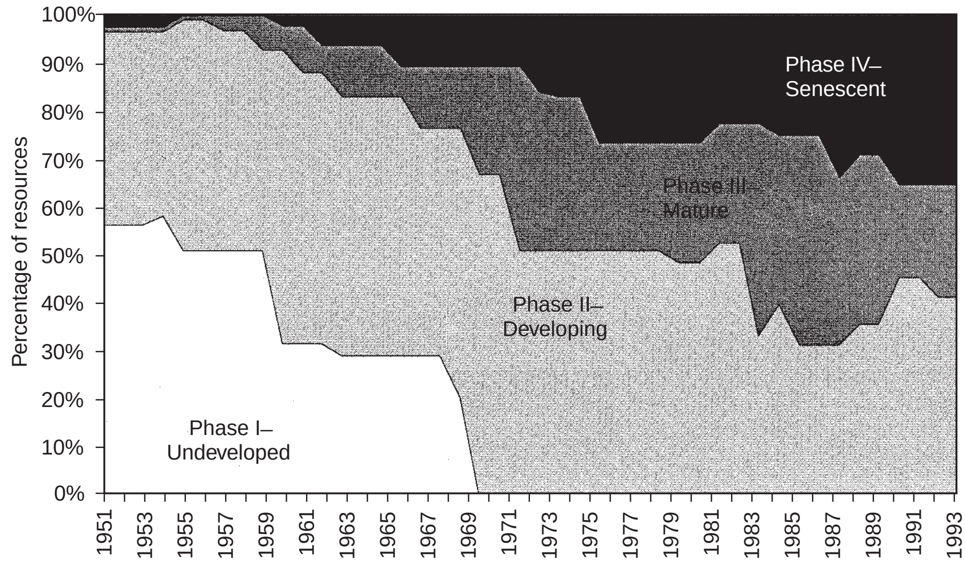

Figure 6 Percentage of major marine fish resources in various phases of fishery development. (Reproduced from Garcia and Grainger, 1996.)

increase in the proportion of stocks classified as 'exploited beyond the MSY limit', i.e., overfished, depleted, or slowly recovering. These conclusions are in line with earlier findings summarized in **Figure 6**.

Being based on a sample of the world stocks, severely constrained by availability of information to FAO staff, the conclusions have to be considered with caution. A key question is: to what extent does the information available to FAO reflect reality? There are many more stocks in the world than those referred to by FAO. In addition, some of the elements of the world resources referred to by FAO as 'stocks' are indeed conglomerates of stocks (and often of species). One should therefore ask what validity a statement made for the conglomerate has for individual stocks (*stricto sensu*). The reply is not available and no research has been undertaken in this respect.

However, it is generally considered that the global trends observed reflect trends in the monitored stocks, because the observations generally coincide with reports from studies conducted at a 'lower' level, usually based on more insight and detailed data. As an example, an analysis on Cuban fisheries using the same approach as used by FAO for the whole world (**Figure 6**), leads to surprisingly similar conclusions, using less coarse aggregations, even longer time series, and with more possibility to 'double-check' the conclusions with conventional stock assessment results.

There is of course the possibility that stocks become 'noticed' and appear in the FAO information base as 'new' stocks only when they start getting into trouble and scientists having accumulated enough data start dealing with them, generating reports that FAO can access. This could explain the increase in the percentage of stocks exploited beyond MSY since 1974. This assumption, however, does not hold for at least two reasons.

1. The number of 'stock items' identified by FAO but for which there is not enough information has also increased significantly with time, from seven in 1974 to 149 in 1999, clearly showing that new entries in the system are not limited to 'sick' fisheries.
2. From the 1980s, based on the recognition of the uncertainties behind identification of the MSY level, and recognizing also the declines due to decadal natural fluctuations, scientists have become more and more reluctant to definitely classify stocks as 'overfished'. The apparent 'plateauing' of the proportion of stocks with excessive exploitation in the northern regions of the World Ocean may in part be due to this new trend.

See also

Demersal Species Fisheries. Dynamics of Exploited Marine Fish Populations. Ecosystem Effects of Fishing. Fish Predation and Mortality. Fisheries: Multispecies Dynamics. Fisheries Overview. Fishery Management. Mariculture Overview. Molluskan Fisheries. Open Ocean Fisheries for Deep-water Species. Open Ocean Fisheries for Large Pelagic Species. Pelagic Fishes. Salmon

Fisheries: Atlantic; Pacific. Small Pelagic Species Fisheries. Southern Ocean Fisheries.

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MARINE MAMMAL DIVING PHYSIOLOGY

G. L. Kooyman, University of California San Diego, CA, USA

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Introduction

Marine mammals are the last major group of vertebrates to adapt widely to the marine environment. Reptiles and birds preceded them by tens if not hundreds of millions of years. The marine reptiles had their greatest success in the Mesozoic. Like the dinosaurs most had disappeared by the end of the Cretaceous, except for sea turtles and crocodiles. Marine diving birds were also present in the Mesozoic, including possibly some penguins. However, as with marine mammals, their greatest diversification occurred during the Tertiary. The lack of competition from such successful and formidable marine reptiles as the mosasaurs, ichthyosaurs, and pleisiosaurs may have enabled this adaptive radiation. Nevertheless, then as now, all three groups had similar physical obstacles to overcome in adapting to marine life. These problems stimulated the evolution of some of the most extreme and unusual physiological and morphological adaptations ever achieved by vertebrates.

The ancestors of whales were the first to begin the invasion of the sea sometime during the Eocene, more than 60 million years ago (Ma). Sea cows, the only herbivorous marine mammal, originated about 50 Ma during the late Eocene, and pinnipeds followed about 30 Ma in the late Oligocene. Pelagic species wander the vast offshore regions of the world's oceans, and dive in waters with depths up to thousands of meters. Because the greatest challenges of the physical environment are preeminent in this region, the pelagic whales and pinnipeds will be discussed in greatest detail.

There are seven major physical obstacles to overcome that require extreme physiological adaptations to life in the oceans.

1. Anoxia: diving into a world that is without oxygen for an air-breathing mammal.
2. Density: just a short distance from the surface the hydrostatic pressure becomes extreme.
3. Breathing: the less time taken for respiration, the more time at depth to search for prey or to avoid being eaten.
4. Vision: even in the best conditions of water clarity in pelagic tropical waters this is a region of twilight to eternal darkness.
5. Acoustics: the limited field of vision underwater increases the importance of hearing over long distances compared to land mammals.
6. Cold: even the warmest tropical sea is 10–15°C cooler than the internal temperature of a hot-blooded marine mammal.
7. Viscosity: there is a reason animals underwater appear to move in slow motion – their movements are slowed by the viscosity of water.

Selection pressure for adaptations to overcome these physical barriers is great and has resulted in some very consistent morphological and physiological adaptations that, in some cases, make it easy to recognize a marine mammal from only a small part of its anatomy. Some of the more salient anatomical features are discussed in relation to their function. Just as there are variations and gradations on the theme of adapting to the marine environment, so too there are extremes that are exemplified by the most pelagic and the deepest divers. **Table 1** shows statistics from each major group regarding the simple assessment of diving ability by the maximum and routine depths and durations. It should be noted that even though the diving ability of some species is impressive, the exploitative ability of marine mammals is superficial considering that the average depth of the world's oceans is 3.5 km and the