PART I: FISHERIES TRENDS

The Global Fisheries Crisis as a Rationale for Improving the FAO's Database of Fisheries Statistics[1]

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ABSTRACT

Global fisheries are in a crisis, and so are the marine ecosystems upon which these fisheries depend. Major policy and management changes are required to halt and reverse the trends that have brought about this situation. Underlying these changes is the need for availability of data sets, pertaining to large areas, that unequivocally demonstrate any large-scale fisheries impacts on marine ecosystems. Not until recently have such secondary data begun to be assembled, although data sets have been available for some time upon which such demonstrations could be based. This applies particularly to the global fisheries statistics assembled and maintained by the Food and Agriculture Organization of the United Nations (FAO), which are assembled by large, arbitrary statistical areas (rather than by ecosystems), and which are not verified against local data sets. The present contribution documents a multi-pronged approach to develop and test a methodology for reconstructing historic catch time series (including misreported catches), and spatially assign these to ecosystems on a large spatial scale. This will serve as baselines for assessing the 'health' of ecosystems, and to evaluate the effects of fishing and management scenarios. Important components of this methodology are a global spatial catch allocation and mapping routine (www.seaaroundus.org), the Ecopath with Ecosim approach and software for constructing food web models of marine ecosystems (www.ecopath.org), and FishBase, an information system on the fish of the world (www.fishbase.org). Along with putting global fisheries data on a spatial ecosystem basis, these tools can greatly contribute to deepening our understanding of the ecosystem services upon which fisheries rely.

INTRODUCTION

In the 1990s, fisheries emerged from their sectoral backwaters, and became one of the environmental concerns of the public at large, at least in the developed countries of the world. This transition in public perception, similar to that involving forestry in the 1980s, was probably due to long established trends suddenly generating media events, e.g., the publication of a report by Alverson and colleague documenting the enormous quantities of by-catch that are discarded by industrial fisheries (Alverson *et al.*, 1994), the collapse of Northern cod (*Gadus morhua*) in Canada (Hutchings and Myers, 1994; Myers *et al.*, 1996; Walters and Maguire, 1996; Myers *et al.*, 1997; Hutchings, 2000), the failed attempt to halt the impending destruction of Southern bluefin tuna (*Thunnus maccoyi*) populations by listing bluefin tuna as an endangered species (Anon., 1996), or the presentation of estimates of the amount of subsidies which contribute to maintaining fishing effort, globally, at levels far exceeding sustainability (Christy, 1997; Garcia and Newton, 1997; Hempel and Pauly, 2002; Munro and Sumaila, 2002; Pauly *et al.*, 2002). These events were only the tip of a gigantic iceberg: fisheries, an industry that had long operated outside of public scrutiny, emerged, to an amazed public, as worse to ocean health than the 'pollution' so much is written about (Dayton *et al.*, 1995). Fishers, whose daring and ingenuity had, for centuries, justified our romantic view of their profession (Kurlansky, 1997), had become cogs in the high-tech machine that almost instantly reduces any stock it touches to a shadow of its former self (Pauly *et al.*, 2002; Christensen *et al.*, 2003; Myers and Worm, 2003).

Particularly important is that 'sustainability', the stated goal of most fisheries management, and enshrined in legislation worldwide, is

[1] An earlier version of this paper was presented at the Fisheries Project Planning Meeting of the Bejier International Institute of Ecological Economics, June 21-23, 1999 in Woods Hole, Mass.

actually a flawed concept. It implies, at best, a maintenance of resources at 'present' levels, usually much below environmental carrying capacity, and, at worst, a gradual erosion of the resource base (Pauly, 1995; Pitcher and Pauly, 1998; Pauly *et al.*, 2002). This is aggravated by 'games' that are played with the logic underlying assessment models. Thus, for example, quickly fishing down newly discovered stocks (such as Orange Roughy, *Hoplostethus atlanticus*) is being justified by surplus-production models, which assume production to be maximized when biomass is reduced to half or less the unfished level. Significantly, however, fisheries are not stopped when the biomass has dropped to half or less the unfished level. Note that we abstain here from probing too deep into the logic of surplus-production modelling and the single-species 'Maximum Sustainable Yield' it implies, earlier criticized by Larkin (1977).

Among professional fisheries scientists, the crisis of fisheries is still often denied. Despite frequent and fashionable references to the need for a methodological 'paradigm shift', many believe, for example, that rigorous quantification of the uncertainties involved in stock assessment, and the communication of the results to fisheries managers in the form of risk assessment would be largely sufficient to resolve the above-mentioned problems. Our key problem, however, is not 'uncertainty', nor lack of knowledge by fisheries managers. Indeed, the problem is not even one of management, but one of public policy. This refers to the excessive role played, in allocation debates, by the users of fisheries resources (i.e., fishing and processing industries) vis-à-vis the true owners of these resources: the citizens (present and future) of the various countries whose fish stocks are being used (Macinko and Bromley, 2002). Resolving this allocation issue requires public involvement, as occurred with, for example, the reclaiming of public waters, long perceived to 'belong' to those who used such waters to cheaply dispose of toxic effluents. Indeed, reclaiming the sea from its abusers will be a key task for humanity in the 21st century; second only to avoiding the massive climatic change that increasing emission of greenhouse gases will give us.

However, informing the public, the true owners of the resources, and the law-makers who represent them, of the true status of the impact of fisheries on ocean health is difficult, as a strong lobby exists which, like the Tobacco Institute with regards to the effects of cigarettes, challenges the obvious to maintain the unacceptable. This implies, among other things, that the data from which the state of the ocean is to be inferred should be transparent and widely available, and thus compelling. An example of the kind of compelling, well articulated case that is meant here is Rachel Carson's *Silent Spring*, which affected public policy via its public impact (Carson, 1962). A step in this direction with regards to the effects of fisheries on our oceans is attempted in Pauly and Maclean (2003).

Developed countries

Fisheries science emerged from the bosom of 'natural history' at the turn of the 20th century, when, following the introduction of steam trawling, coastal catches and catch per effort began to decline in the North Sea and other fishing grounds around the North Atlantic (Cushing, 1988). The scientific response, which included the foundation of ICES, the International Council for the Exploration of the Sea (Went, 1972), is well documented (Smith, 1994), and involved great scientific achievements, notably the development of the first unifying theory in fisheries science, described in Beverton and Holt (1957), and the first functional simulation model of a fisheries resource system (Andersen and Ursin, 1977). This led to Multispecies Virtual Population Analysis (MSVPA), a tool for understanding trophic interactions among exploited species (Daan and Sissenwine, 1991). Similar developments occurred in North America, both on the east and west coasts (Ricker, 1975; Hilborn and Walters, 1992), and in other developed countries and areas, notably Eastern Europe, East Asia and the Southern Hemisphere. Still, it is also in those areas, particularly in the North Atlantic and North Pacific, that ecosystem effects of overfishing are most visible (Pauly and Watson, 2003), notably due to fisheries over time catching species progressively further down the food webs (Pauly et al., 1998; Pitcher, 2001).

Developing countries

The colonial areas which, after the Second World War gradually became what are now called the 'developing' countries of the world, had long traditions of fishing, if mostly at artisanal levels. Since the 1960s, these fisheries have been gradually pushed aside by industrial fisheries, either in the form of distant-water fleets from developed countries, e.g., as in much of West Africa (Kaczynski and Fluharty, 2002), as nominal or real joint ventures, e.g., many tuna fisheries in the South Pacific (Melzhoff and LiPuma, 1983), or in the form of trawler and other fleets owned by local elites (e.g., the trawl fisheries in Southeast Asia) but often subsidized by major development banks, e.g., the Asian Development Bank (Mannan, 1997).

The scientific inputs to these developments, devoted mainly to resource surveys, were minimal (Pauly, 1996a), a reflection of the weak scientific infrastructure of the countries in question. The bulk of the populations exploited by these fisheries have now collapsed, or are much depleted (Silvestre and Pauly, 1997).

However, in retrospect, it appears that more input from the fisheries sciences extant at the time would not have prevented these developments: tropical fisheries science – a derivative of the science prevailing in Europe and North America – was as unequal to its tropical task as its role model was to its temperate task (Pauly, 1998). This, and similar issues related to fisheries in developing countries, are not 'sideshows' that may be ignored when dealing with global fisheries issues: these countries now generate over 50% of global marine fisheries catches (Christensen *et al.*, 1992; Anon., 1995a). Moreover, a very large fraction of their catches enters the world market, increasingly at the detriment of the exporting countries (Atta-Mills *et al.*, 2004).

Time series of catch statistics

The most important information about a fishery is the total catch, by species, over time. Catch statistics are important for three reasons: (1) the gathering of statistics increases knowledge of the fishery (tracking of vessels engaged in fishery, dockside sampling of these same vessels, etc.); (2) total catches determine the scale of fisheries, both within and between sectors, in terms of their size and value; and (3) examining time series of catches allows for first-order assessment of the fisheries over time, and of the status of the species and populations (stocks) upon which the fisheries depend (Caddy and Gulland, 1983; Grainger and Garcia, 1996).

Fisheries catches may be separated into three components: (i) nominal catch, which is reported to (and by) a monitoring agency (e.g., by member countries to the Food and Agriculture Organization of the United Nations [FAO], in the case of global fisheries statistics); (ii) discarded by-catch, the non-targeted part of a catch, often consisting of the juveniles of targeted or other species, caught due to the unselective nature of the gear used, and usually thrown overboard (generally unrecorded) rather than landed (Alverson *et al.*, 1994; Alverson and Hughes, 1996); and (iii) an unreported component, consisting of categories not covered by the reporting system in question, including sport fisheries catches, artisanal fisheries catches and illegal catches (Castillo and Mendo, 1987; Agnew, 2000; Pitcher *et al.*, 2002).

Thus, item (iii) may be composed of catches that a given agency is not mandated to gather and report, so-called 'unmandated catches', and of catches whose value may be maliciously misreported, i.e., 'disreported catches' (Pitcher *et al.*, 2002). A major task, thus, is to estimate IUU catches (Bray, 2000), a task that requires the development of new protocols (Pitcher *et al.*, 2002).

The role of FAO

The role of the Food and Agriculture Organization of the United Nations (FAO) in international fisheries research and management has been considerable, and may be divided into three phases: (1) an early 'North Atlantic Phase', lasting from the post WWII founding of FAO to the mid-1960s, devoted to the development of standardized methodologies, and involving mainly scientists from or in Northern Europe; (2) a 'Developing-Countries Phase', lasting perhaps to the late 1980s, with FAO supporting crucial initiatives in developing countries (workshops, training courses, taxonomic guides, regional commissions); and (3) a 'Global Phase', in which FAO deals with fisheries on a decidedly worldwide basis, reflecting the globalization of fisheries issues: development of the UN agreement on straddling stocks (Anon., 1995b, 1995c), the Code of Conduct for Responsible Fisheries (Anon., 1995a), global evaluation of the status of fisheries (Grainger and Garcia, 1996), etc.

FAO (www.fao.org/fi/default_all.asp, date accessed: 20 November 2003), emphasizes the following elements of its mission: "*to promote sustainable development of responsible fisheries and contribute to food security. To implement this [...], the Fisheries Department focuses its activities, through*

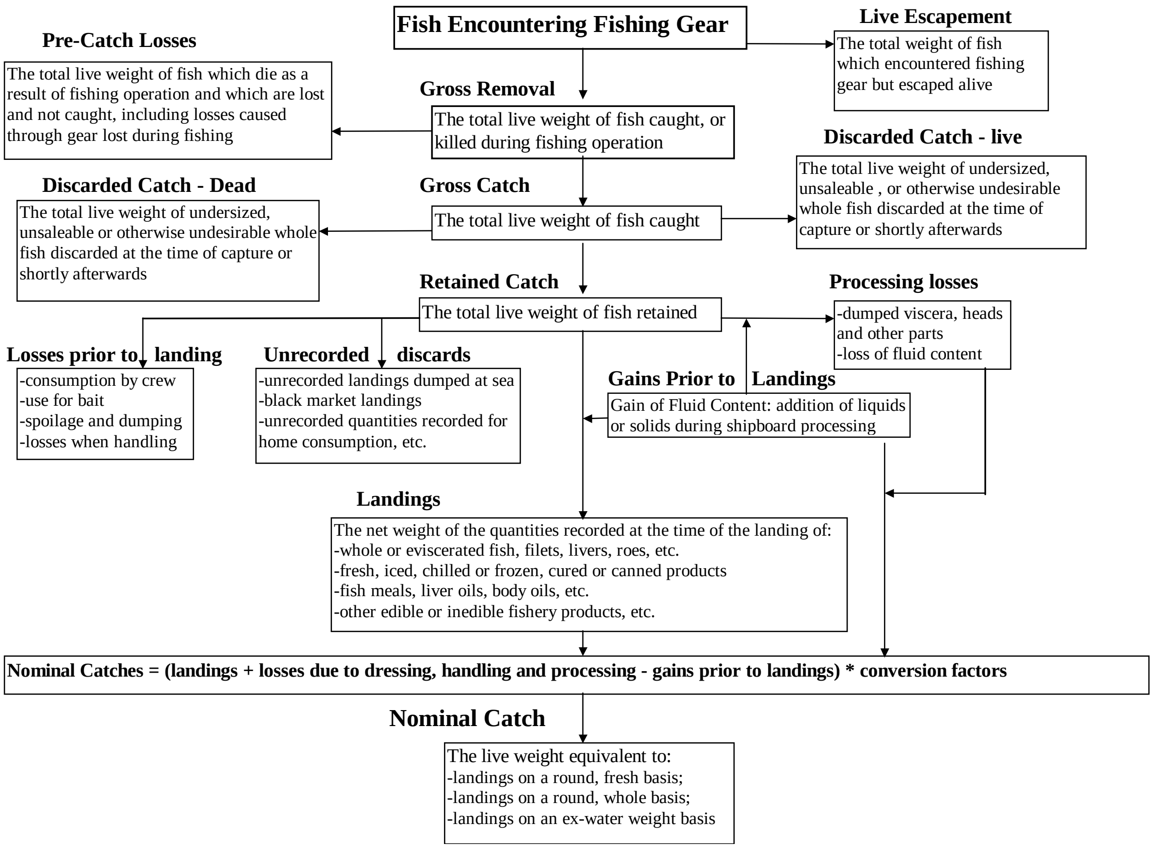

Figure 1: Flowchart of steps involved from ‘fishing’ (fish encountering fishing gear) to estimation of nominal catch (from the 1994 FAO Yearbook); these steps represent procedures that *should* be used, not necessarily those that are actually used by the entities submitting data to FAO.

programmes in Fishery Resources, Fishery Policy, Fishery Industries, and Fishery Information, on three medium-term strategic objectives:

- *Promotion of Responsible Fisheries Sector Management at the Global, Regional and National Levels, with priority given to the implementation of the Code of Conduct for Responsible Fisheries, Compliance Agreement, International Plan of Action and particular attention paid to the problem of excess capacity and the provision of advice for the strengthening of Regional Fisheries Bodies...*
- *Promotion of Increased Contribution of Responsible Fisheries and Aquaculture to World Food Supplies and Food Security. Following on the outcome of the Kyoto Conference on the Sustainable Contribution of Fisheries to Food Security, the Department focuses on reduction of waste in fisheries (particularly discards) and aquaculture (including its promotion in the context of FAO's Special Programme for Food Security). Support is given to aquaculture development in areas of highest potential or critical need by improving aquaculture resources utilization and integration with agriculture, promoting research as well as protection and rehabilitation of the environment.*
- *Global Monitoring and Strategic Analysis of Fisheries, with priority given to development of databases and analysis of information using modern information systems (e.g. CD-ROM, GIS), and contributing inter alia to the publication of the State of World Fisheries and Aquaculture (SOFIA) on a biennial basis and the Digital Atlas on Agriculture, Forestry and Fisheries”.*

Until recently, many fisheries scientists were not fully aware of FAO's role in fisheries, and of the large literature this has generated, largely because, outside of FAO projects, FAO documents are available only through specialized outlets, at relatively high prices. Fortunately, the Internet is changing this, as much of this material is now becoming accessible through the World-Wide-Web. On the other hand, most fisheries scientists and marine biologists are aware of FAO's role in establishing a Code of Conduct for Responsible Fisheries (Anon., 1995a), and in compiling and maintaining global fisheries statistics, although they may not know the underlying mechanisms.

The key steps used by FAO in compiling global catch statistics are summarized here through a graph (Figure 1) adapted from the 1994 FAO Yearbook. Hall (1996) and Alverson and Hughes (1996) discuss the by-catch problem implied in Figure 1, an area of much concern for all involved in fisheries statistics and management, and to the public at large. However, the single most important aspect of the system in Figure 1 and the subsequent adjustments at FAO Headquarters, is that it generates a *global* data set of landings – the only one in the world. Moreover, because so many countries and institutions contribute to it, there is a strong sense of ownership. Rarely does one find any criticism of this system put into print (Chua, 1986), though all practitioners are aware of at least some of its deficiencies, satirized in Mariott (1984), and expanded upon in the next section. As well, the recent discovery of significant over-reporting of fisheries catches by China, which drastically influenced global pattern of catches for the 1990s (Watson and Pauly, 2001) is mentioned in FAO statistical reports, if only tacitly (notably by presenting data with and without China, e.g., Garcia and de Leiva Moreno, 2003).

Earlier proposals for improvement

Critical comments on the FAO datasets are difficult to justify: after all, this is 'all we have got'. On the other hand, it is obvious that the FAO statistical system, even though recently upgraded, is in great need of improvement. For example, the first report of FAO's new 'Advisory Council on Fisheries Research' noted that "*the current statistics collection system is limited to primarily landings and commodity statistics, whereas there is a critical need for data relevant to fleet capacity, participation in fisheries, economic performance and distribution*" (Anon., 1997), which is what Pontecorvo (1988) had asked for over a decade ago. However, collection and standardization of such statistics – except for fish prices - is difficult, and FAO, perhaps rightly, did not follow up on these suggestions, now reiterated in the above-mentioned report, but without reference to Pontecorvo's earlier plea, nor to the lively debate that ensued (Gulland, 1989; Pontecorvo, 1989; Robinson and Christy, 1989). Moreover, while adjuring FAO to emphasize an '*ecosystem perspective on fisheries*', its Advisory Council on Fisheries Research failed to mention the corresponding requirement for its statistical data to be put on an ecological basis (also part of Pontecorvo's plea).

Complementing the FAO monitoring system

It is obvious from this and related documents that the world scientific community must assist FAO in expanding the coverage of its statistical reporting system. There is a need for the international community to create and maintain a relational database compatible with FAO's FISHSTAT database, but which splits over-aggregated time series into finer categories, incorporates previously ignored sport, artisanal and other under-reported catches, and adjusts official figures to account for illegally caught fish.

A crucial element in the gradual evolution of such a database would be an international network of collaborators. These collaborators, many drawn from the academic and conservation communities, would supply the group managing the database (officially or privately) with reports and data sets that would help enrich the database with information presently not covered by FAO. The subsequent publication (through the World-Wide-Web) of otherwise unavailable fisheries data would induce greater transparency overall, and would help FAO in the fulfillment of its mandate to cover global fisheries.

Most importantly, however, this database should re-express the FAO catch statistics, presently aggregated into 18, largely arbitrary 'statistical areas' into catches extracted from marine ecosystems, i.e., into the entities from which this biomass is extracted, and which we would like to see persist as functional entities.

Thus, one way this can be achieved is to create a system that would complement the existing FAO database such that it can be used in ecological contexts, as well as account for those elements (such as illegal fishing), which private groups could follow in greater depth. Attempts to achieve just that are presently underway, e.g., through the *Sea Around Us* project at the University of British Columbia Fisheries Centre (see www.seaaroundus.org), and have already yielded significant results (Watson and Pauly, 2001; Pauly *et al.*, 2002; Christensen *et al.*, 2003; Pauly and Maclean, 2003).

Putting fisheries in their ecosystem context

An ecologically-based stratification, consisting of 56 'biogeochemical provinces' already exist, which can replace the FAO statistical areas (Longhurst, 1998). Being based on satellite oceanography, this stratification relies on the very 'stuff' that generates fundamental differences between ocean provinces: sea surface temperatures and their seasonal fluctuations, and pigments such as chlorophyll and their fluctuations. Marine systems differ from terrestrial systems in that their productivity is essentially a function of nutrient inputs to illuminated layers. This gives a structuring role to the physical processes which enrich surface waters with nutrients from deeper layers, such as wind-induced mixing, fronts, upwellings, etc. Thus, the location, duration and amplitude of deep nutrient inputs into different biogeochemical provinces - as reflected in their chlorophyll standing stocks - largely define the upper trophic level biomasses and fluxes that can be maintained in these provinces (Longhurst, 1998).

The flux of primary production into grazers such as krill, and the subsequent consumption of these herbivores by carnivorous zooplankton and small fishes can be straightforwardly modelled based on the mass balance approach, as can the fluxes into higher trophic levels, all the way to the top predators exploited by fisheries (tuna, billfishes), and those that compete with us (marine mammals). Indeed, the assumption of mass-balance allows quantifying fluxes to and from groups whose biomass is not known, such as deep-sea squids, consumed by sperm whales, and lanternfish, consumed by dolphins. This allows dealing with a type of resource presently not quantified by those evaluating the overall potential of the ocean, and whose estimates are often based on guesswork (Pauly, 1996b), although they involve taxa whose combined biomass has been variously guessed to be in the order of several billion of tonnes.

Mass balance models can be constructed straightforwardly using the Ecopath with Ecosim and Ecospace approach and software, located at www.ecopath.org (Polovina, 1984; Christensen and Pauly, 1992; Walters *et al.*, 1999; Pauly *et al.*, 2000). Thus, the Ecopath-based description of specific ecosystems outlined above can be raised to their corresponding biogeochemical provinces, then to ocean basin scale and finally to the global ocean, taking into account the fraction of coastal waters, shelf, deep ocean, etc. in each of these area. Christensen *et al.* (2003) and Pauly and Maclean (2003) document results obtained through this methodology for the North Atlantic.

This approach combines into a single framework the detailed data sets available at local scales for all ocean provinces (results of historic trawl surveys, acoustic biomass estimates, biomass estimates from single-species assessments, diet compositions analyses, food consumption estimates from laboratory studies, and other data sets, including data in FishBase, see below), and raise these to the level of ecosystems, as required for inferences on the impacts of fisheries. This also allows, using Ecosim, the dynamic simulation module of this software (Walters *et al.*, 1997), to quickly identify, for any ecosystem, the gross features of the management regime required that might optimize catches, given the establishment of marine protected areas (Pauly *et al.*, 2002; Russ and Zeller, 2003), the requirement to protect the food supply of marine mammal populations, and other conservation-relevant constraints (Hempel and Pauly, 2002; Pauly *et al.*, 2002).

FishBase and other biodiversity databases as information systems for fisheries

FishBase (Froese and Pauly, 2000), located at www.fishbase.org, presents key nomenclatural, distributional, biological and other information (including catches, where available) on over 28,000 extant species of finfish. Until 2000, the FishBase CD-ROM included an annually updated version of the global FAO catch database presented above, made accessible through the SPECIES, and

COUNTRIES tables of FishBase. The catch database of the *Sea Around Us* Project is compatible with FishBase, as this enables direct access to the most authoritative nomenclature of fish presently in existence (that of Dr. W.E. Eschmeyer, of the California Academy of Science, also included in, and updated through FishBase). This resolves, in one fell swoop, one of the biggest problems of database covering different taxonomic entities.

However, fisheries (and ecosystems) are not restricted to fishes. Thus, other taxonomic components and data-sources also need to be considered, e.g., through joint initiatives such as the standardization and cross-linking of existing databases currently being undertaken with CephBase (www.cephbase.org), or the creation of new biodiversity data sources such as the Scientific Expeditions Database being developed by M.L. Palomares of the *Sea Around Us* project.

CONCLUSIONS

The world community has made, through FAO, a massive investment to create and maintain a database of global fish catches. This is an investment of great usefulness, and with an even greater potential. To fully realize the potential of this database, however, an additional effort needs to be made to put the time series of catches it contains on an ecosystem basis, and in the process, to verify and amplify its contents (as done in the various contributions in this volume). The first steps in this direction are being undertaken by the *Sea Around Us* Project, the FishBase Consortium and other groups. We hope that these efforts will remove 'lack of data' from the excuses used to justify the state our fisheries are in, and increase public transparency and understanding, leading to increased involvement in public policy by the true owners of ocean resources, the present and future citizens of the world.

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