OCEANS AS MAJOR RESERVOIRS OF PROTEIN

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Summary

The ocean is currently perceived as a limitless and generally pristine source for food resources. This presumption is largely false and has lead to the current near-crisis state of many of the wild-capture fish stocks. In this article we will demonstrate that while fish do provide an excellent source of high quality protein, many fisheries have reached or exceed sustainable levels. It is unlikely that wild fisheries yield will increase substantially, and likely that future increases in food production will come from improved fisheries management or utilization of by-catch and other wasted or discarded product. Production from marine aquaculture is increasing rapidly, and the eventual sustainable yield of this emerging agro-industry cannot yet be predicted. However, concomitant with the spread of marine aquaculture are increasing concerns about the

potential for environmental impact and degradation resulting from nonsustainable culture practices. As the industry matures, better husbandry practices and improved performance of farmed stock will improve the economic and environmental sustainability of marine aquaculture. Nevertheless, marine aquaculture, as it is presently practiced, is resource and energy-intensive, with products targeting high-cost specialty markets. If this trend continues into the future, marine aquaculture will not contribute significantly to the alleviation of protein deficiencies in the developing world.

1. Introduction

The world oceans cover vast extents of the surface of the globe and humans have long considered them to be a pristine and boundless reservoir of resources and a limitless dumping ground for all manner of wastes. Increasing evidence of environmental degradation and declining yields of many wild fisheries are symptoms of the fallacy of this belief. While the oceans can provide a source of high-quality protein, marine resources are not limitless and their exploitation must be managed with caution and care to ensure continuing environmental and economic sustainability.

2. Oceanic Primary Production

Net primary production in the oceans (50 to 55 Pg C y^{-1}; 1 Pg = 10^{15}g) is about the same as on land (55 to 60 Pg C y^{-1}), however since the standing stock of plant biomass is in the ocean is 500- to 1000-fold smaller than on land (450 to 500 Pg C), carbon turns over on the scale of days in the ocean compared with tens of years on land. Less than 10% of oceanic primary production is harvested (aquaculture and wild fisheries) providing 6% of the global human protein requirement. This contrasts with a harvest of 35–40% of terrestrial primary production to provide the remaining 94% of human protein requirements. The plant biomass that sustains the terrestrial and oceanic food webs that feed humankind differs, by nearly three orders of magnitude. In addition, most of the terrestrial plant production that is channeled into animal protein occurs on cropland where the plant biomass is ~3 Pg C and production is 4 to 7 Pg C y^{-1}. Thus, the role of land-based protein production is even greater, per unit plant production and biomass, than global values indicate.

Ocean resources utilized by humans include wild or capture fisheries and marine aquaculture. Exploitation of ocean production has increased steadily at a rate of 1.85 metric tonnes (mt) per year over the past 50 years to almost 110 x 10^6 mt wet weight during 1999 (Figure 1). Capture fisheries increased to approximately 85 x 10^6 mt by the mid-1980s and have since remained relatively stable. The contribution of marine aquaculture to total ocean harvest has increased from less than 5% to over 20% during the past 30 years. Including aquatic plant production, marine aquaculture now produces 25 x 10^6 mt per year. Capture fisheries provide fish for both human consumption and for production of fishmeal and other components of livestock food. Fishmeal and oil production accounts for approximately 35% (30 x 10^6 mt) of the capture fishery landings. The remaining 65% is used for direct human consumption. While capture fisheries may now be at their maximum sustainable level, rapid increases in aquaculture production are anticipated to continue the trend in increased ocean yields for direct human consumption.

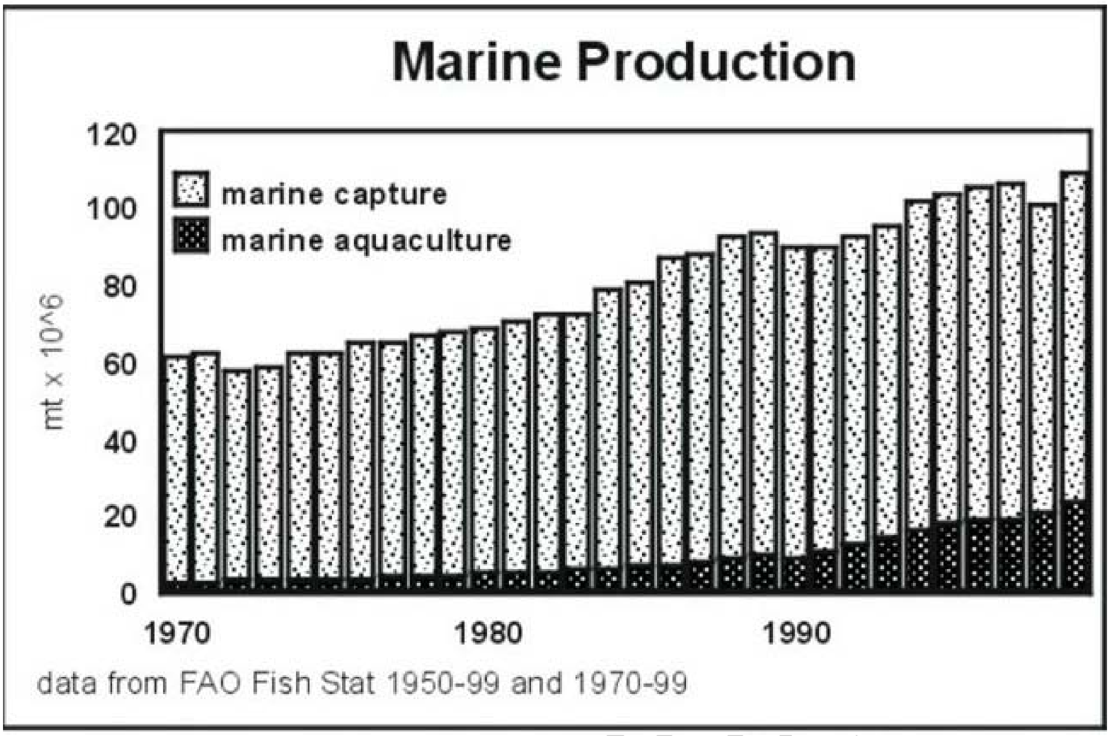

Figure 1. Global production of marine aquaculture and capture fisheries in metric tonnes (mt) x 10^6 per year from 1970 to 1999. Data are from FAO FishStat databases for 1950–99 (capture fishery) and 1970–99 (aquaculture).

3. Capture Fisheries

3.1. Current Production and Trends of Marine Fisheries

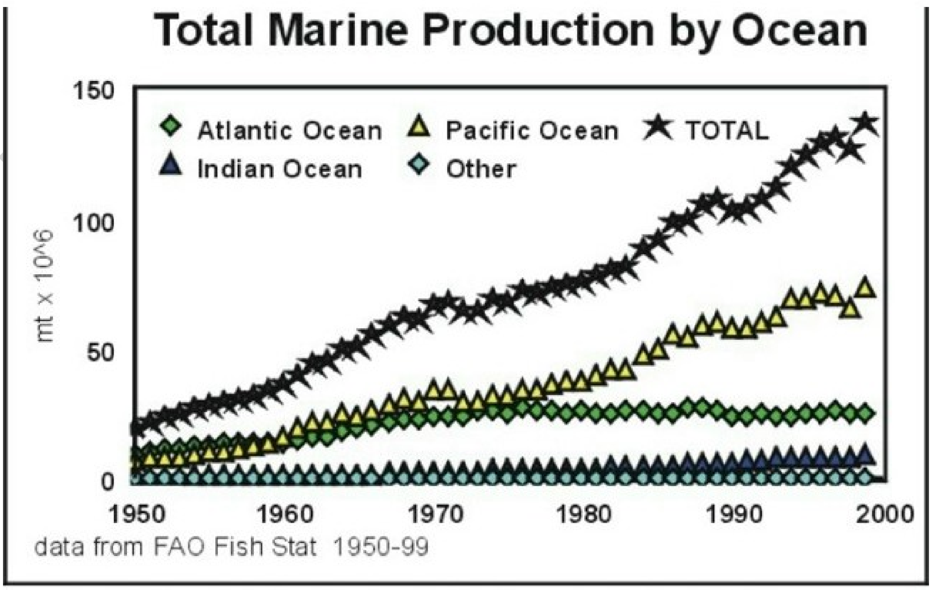

Figure 2. Marine production (aquaculture plus capture fishery) by ocean in metric tonnes (mt) x 10^6 per year from 1950 to 1999. Data are from the FAO FishStat database for 1950–99.

The rate of increase in global production from capture fisheries has slowed considerably since the 1950s. Since the 1970s, production from the Atlantic Ocean, which then represented 40% of the total, has remained relatively stable (Figure 2), while production from the Pacific Ocean sector increased steadily until the late 1980s, and now represents almost 65% of total landings. Indian Ocean production has also increased and now provides about 10% of marine landings. Production from other oceanic regions has remained at less than 1% of the total over this time.

For the world's 200 major fisheries, which account for over 75% of total landings, 35% are considered to be senescent (show a declining yield), 25% are mature (plateauing at high exploitation levels) and 40% are developing (show an increasing yield). This suggests that at best and with careful management, only 40% of the major fisheries have the potential for increased harvest, and these may yet be offset by overexploitation of mature fisheries and further decline of senescent ones.

When compared with terrestrial production systems, ocean harvest tends to be energetically inefficient. As production at one trophic level is consumed by the next, only a portion is incorporated into biomass. The rest is metabolized, excreted, or defecated. As a result, in long food chains, only a small fraction of solar energy (or biomass of primary producers) is incorporated into biomass at the top trophic levels. Transfer efficiency between trophic levels is often estimated to be on the order of 10%. On land, the majority of protein production comes directly from plants or from herbivores (that is, trophic levels 1 and 2), whereas in the ocean, most protein production comes from higher trophic levels. Currently, fishers harvest 3% of total production from trophic levels 2–3, 42% of production from trophic levels 3–4, and 38% of production from trophic levels 4 and above.

Upper trophic level species have long been a preferred target of fishers. However, as ecosystems react to intense fishing pressure on the upper trophic levels, fishers have been obliged to concentrate on lower trophic levels. This practice termed "fishing down the foodweb," is considered an indicator of significant changes to marine fish communities in consequence of fishing activity. As a result, the average trophic level harvested in most oceanic regions has been declining, and the global average trophic level harvested is now about 3. This is still two levels above most terrestrial producers.

Over the past decade, it has been recognized that by-catch and discards may account for a significant and unreported component of wild fishery catches. By-catch is the capture of non-target species or size classes captured during a directed fishery. The by-catch is often dumped or discarded at sea and is usually not reported as part of the harvest. As a result, accurate estimates of by-catch have been difficult to obtain. First estimates of world by-catch made in 1994 were between 17 and 40 x 10^6 mt. More recent estimates place this at 20 x 10^6 mt, equivalent to 20% of the total reported catch. As understanding that ocean production is not limitless has grown, major initiatives have been undertaken to reduce by-catch and to properly document the resultant losses. By-catch varies greatly depending on the type of fishery, the gear used, and management practices. For some fisheries (artisanal and subsistence fisheries for example) it is close to zero, while for others (trawling for shrimp and other cragonids) it may equal to or exceed the catch of the target species. Recent efforts to reduce by-catch include modifications to gear (for example, mesh size of nets), to species retention practices (limitations of high grading and increased use of multiple species), and to fishing practices (management practices and reporting practices). These have significantly reduced by-catch in some fisheries. For example, the yellowfin tuna fishery in the eastern tropical Pacific has reduced the number of dolphins killed from hundreds of thousands to fewer than 3000 per year by implementing gear modifications and operational changes, while the Gulf of Mexico shrimp fishery has reduced the number of sea turtles killed by use of turtle exclusion devices on the trawls.

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Biographical Sketches

M. Robin Anderson is a Marine Habitat Research Scientist at the Northwest Atlantic Fisheries Centre of the Canadian Department of Fisheries and Oceans in St. John's Newfoundland. She obtained her Ph.D. in Biology (ecology of freshwater aquatic plants) at McGill University, Montreal and her M.Sc. (ecology of kelp in the St. Laurence Estuary) and B.Sc. in Biology at Laval University, Quebec City. Dr. Anderson's research program focuses on the effect of human activities on the marine environment. Her current projects include the environmental effects of finfish and shellfish aquaculture, mercury in marine foodwebs, impacts of marine tailings disposal, and of offshore oil production. She also carries out research on the role of microzooplankton in carbon and nutrient cycling in the oceans and is currently an investigator in the Canadian Surface Ocean Lower Atmosphere Study (SOLAS).

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