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The Promise of the Blue Revolution (Extended version)

Aquaculture can maintain living standards while averting the ruin of the oceans

By Jeffrey D. Sachs

Environmental sustainability is already very difficult to achieve with today's 6.6 billion people and average economic output of \$8,000 per person. By 2050 the earth could be home to more than nine billion people with an average output of \$20,000 or more, putting vastly greater pressures on the Earth's ecosystems if technologies of production and consumption remain largely unchanged. Many environmentalists take it for granted that richer countries will have to cut their consumption sharply to stave off ecological disaster.

There is another approach. Global public policies and market institutions can promote new technologies that raise living standards yet reduce human impact on the environment. A crucial group of such technologies is aquaculture, the farming of marine animals, which can support growing human consumption of fish and other aquatic species while relieving intense pressures on ocean ecosystems. The rapid development of aquaculture in recent years has been likened to a "Blue Revolution" that matches the Green Revolution of higher grain yields from the 1950s onward.

Between 1950 and today the total landed catch from open- and inland-sea fishing almost quintupled, from around 20 million to about 95 million metric tons. Both higher demand from rising world incomes and higher supply from more powerful fishing vessels contributed to the surge in the catch and consumption of fish. So, too, did large and misguided subsidies to fishing fleets, reflecting the political power of geographically concentrated fishing communities and industries. The world put itself on a course to gut ocean ecosystems, with devastating consequences.

Into the breach has arrived the Blue Revolution, first in China, and now in many other parts of the world. Aquaculture yields have increased from around two million metric tons in 1950 to almost 50 million metric tons today. Thus, even though the global fish catch peaked in the late 1980s, aquaculture has enabled a continuing rise in human consumption of fish. China now accounts for around two thirds of total aquaculture production worldwide by weight and roughly half by market value.

Fish farming in China is of course an ancient activity, with several carp species grown among rice fields for thousands of years. The inter-mixing of rice production with fish farming, rather than with animal husbandry as in Europe and the Americas, made good ecological and economic sense in densely populated China. A cow requires around seven kilograms of feed grain for each kilo of meat, while a carp requires around three kilos or less. Fish farming economizes on feed grain, and of course on the land area needed to produce it.

The exciting news, however, is that recently Chinese scientists have both improved the efficiency of aquaculture and revolutionized the range of species that can be farmed. An insightful study by coastal ecologist Carlos Duarte and his colleagues in the April 7 *Science* documents the dramatic rate of domestication and commercialization of marine species. Of the more than 400 farmed marine species, as many as 106 have been domesticated in the past decade alone. In contrast, there has been almost no concurrent increase in the number of domesticated land species.

Aquaculture by itself will not solve the crises facing marine ecosystems. For instance, even with the vast increase of farm-raised fish, the farming of salmon and other fish-eating species keeps pressure on the oceans because massive amounts of catch are needed to feed them. The aquaculture of herbivorous fishes, such as carps, tilapia and catfish, is vastly more sustainable, yet even in this case, aquaculture poses significant ecological challenges. Aquaculture can spread diseases from farmed to wild fishes, pollute nearby waters with excess nutrient loads, lead to habitat destruction such as the clearing of mangroves for shrimp farming, and threaten genetic diversity through the release of farmed species into the wild. Yet better aquaculture technologies are already evolving rapidly to face these challenges. As with any promising technological development, public policies will play a critical role through a judicious use of policy carrots and sticks. Public funds and prizes should be used to promote research on aquaculture technologies.

At the same time, the pillaging of the oceans will continue unless regulations such as tradable fishing permits that limit the total catch to sustainable levels are also used to contain the exploitation of the ocean commons. Subsidies for excessive ocean fishing should also be slashed. Egregious practices such as bottom trawling on seamounts should be outlawed by international agreement. With sensible global policies, the Blue Revolution can indeed become a major force for improved human nutrition, economic well-being and

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