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The Future of Fish as Food

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The wild fishery harvest of 2012 according to FAO was 91.3 mmt, combined with farmed seafood production of 66.6 mmt, places global seafood supplies at 158 mmt, or 125 mmt of food species substracting reduction fisheries of 33 mmt (excluding the approximately 24 mmt of harvested aquatic plants used for industrial and food production). This was a 3.15% increase per annum from 2010. With wild caught amounts expected to remain stable, aquaculture must increase at over 8% per annum to meet increased demand and increased population. Will freshwater and marine farmed production be able to continuously increase at that rate? The answer is yes for the short term with intensification and available land and water resources in resource-rich countries, but doubtful in the long term, as water and land are limited resources.

A major factor affecting global supplies and production will be climate change. As climate warms, fish stocks will move to find their preferred temperatures. However, tropical stocks would likely not be replaced with other stocks as no warmer water stocks exist. Adaptation to higher temperatures by tropical fish stocks would be the only option for maintained harvest in these areas. Increased production could even be a possibility with faster fish growth with higher temperatures. As coral communities are part of the ecology of reef stocks, and coral communities are expected to be negatively impacted by rising temperatures and acidification, certainly some reduction at best will occur in coral reef-based fisheries. Increased variability in climate will impact production elsewhere through droughts, floods, storms, and temperature extremes.

The result will be increased prices, and perhaps increased environmental impacts. Additional pressures will be exerted on wild stocks that are in the "commons", with no nation or private concern controlling their exploitation. Even with control, some countries may choose to overexploit their resources. Undoubtedly, the result would be extinction of some stocks, if not species (e.g. sturgeons). Are we at maximum sustainable yield? At present, with current technology, I would posit we are close. However, the following areas, with new technologies, may be areas of potential growth.

Freshwater aquaculture is near (Europe and US) or probably above (SE Asia and China) sustainable levels. Only Africa and South America have large unutilized freshwater resources. Freshwater production exceeds marine at present, due to the longer history of freshwater aquaculture. Africa could add the equivalent of South America, but many obstacles remain for this to occur, including infrastructure, internal and external political and cultural instability, and education. Indications are 12 mmt additional production is possible. With new technologies of intensification and reduced environmental impact, a doubling to 24 mmt would be optimistic, but not unrealistic.

New technologies hold the promise of intensification and the utilization of unfavorable environments for aquaculture. The improved airlift aerator of Dr. William Wurts would increase limiting oxygen levels for intensification at reduced cost, compared to currently used paddlewheel aerators. Adding a complementary species, such as tilapia in freshwater systems and seaweed and shellfish in marine, will increase intensification, sustainability, and more importantly production. A complementary species would utilize the wastes of the fed species, requiring no additional feed. A reciprocating aquaculture or synergy would result with the presence of each adding to the benefit of the other at little cost. A doubling of production intensity may be possible from research results. Aquaponics is a related concept, whereby aquatic animal species are fed and produce nutrients for the plant component. The plant component, unlike in the reciprocating polyculture example, is the major income producer. These systems would be placed wherever the market exist, but would be high value and would not be expected to add substantially to global production.

Marine aquaculture is growing at a more rapid pace that freshwater and has greater scope from the vast amount of saltwater, new technologies and species. Shellfish as mentioned will be an important, if not most important, growth area. Shellfish can be grown suspended utilizing the entire water volume, resulting in the highest per area production at present, as well as attached to the substrate. Algae (e.g. seaweeds) will become a greater part of our diet, in one form or another similar to the revolution in use of terrestrial plant proteins (soybeans). The potential may be limited to protected areas, depending on new technologies. The use of seaweeds and shellfish in polyculture or integrated multitrophic aquaculture (IMTA) to achieve greater sustainability in fish culture is certain to increase. Challenges include: technologies to expand beyond sheltered coastal areas profitably, climate change with variable destructive oceanic storms, environmental regulations mandating land-based marine production, and cost of the product (which will be high). Additional production should double from 2012 levels of 28.5 mmt to 57 mmt.

Marine wild fisheries also could increase. Increased temperatures and land-based nutrient input as well as marine aquaculture nutrients will increase oceanic primary productivity. As the base of the food chain enlarges it will provide "bottom up" movement to increased higher trophic level production, and increased catches will result. These may be lower trophic level species such as squids and filter-feeding fishes (sardines, mackerel, herring, etc), but these are human healthy fishes, high in healthy fats, so the net result could be increased human health, if not satisfaction. How many consume large quantities of sardines, other than Mediterranean countries or others with a culture of these species? A caveat is increased ocean acidification. At present, the major impact appears to be on shellfish, which are among the fastest growing in volume of cultured marine products and are high value crops. Increased primary productivity and culture of shellfish could provide major growth areas if acidification is not as dire as it now seems (or if anthropogenic carbon dioxide levels stabilize). Many human civilizations, present and extinct, have depended on shellfish and it seems this trend will also increase with modern civilization. Acidification will also impact corals by making it harder to produce their calcium carbonate colonies and in turn impact fish that depend

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on them. Along with increased primary productivity and resulting fish stocks, a reduction In the use of marine fish meal and fish oil could make available much of this major fishery for human use and marine mammals and birds. What is the potential growth: perhaps the level of current fish capture for meal production of 33 mmt. Combined with the additional freshwater and marine aquaculture production, the potential for additional global seafood supply may be on the order of 114 mmt. Although this is an increase of 72% from 2012, by compounded calculation it represents approximately 25 years of additional supply at the recent 3.15% per annum growth rate. Reductions in population growth and per capita consumption would reduce the needed growth rate and extend the supply. Herein lies the wild card. Who will benefit from these new sources of production?

Fish is presently a major source of global animal protein for developing nations. This results from wild fish stocks traditionally being the cheapest source of animal protein. As we have indicated, the cost of seafood will rise in coming decades. Fish may well become beyond the resources of the vast numbers of "poor" populations. What they will consume for protein to replace fish is a major and unaddressed issue. Poverty in some developed countries (Ie. USA) is actually increasing and is not greatly decreasing in developing countries. Food is an issue that could spark conflict. Water is and will be another.

Water supplies are limited and essential for human existence. Without water, humans will perish in several days, long before food deprivation. Clean water is another issue. Humans are and will be increasingly forced to drink and use unclean, unsafe water supplies. For example, the presence of arsenic in well water supplies in Bangladesh has not reduced consumption, only health. Water supplies for basic human needs take precedent over food production, although aquaculture is most efficient in using water for animal production and is getting better with less degradation. Unless countries work together to sustainably use water resources and reduce income inequality, the above is just as it is: A projection assuming the current dominant civilization will exist.