Review of the Status, Trends and Issues in Global Fisheries and Aquaculture, with Recommendations for USAID Investments

USAID SPARE Fisheries & Aquaculture Panel[1]

Objectives:

(1) To provide a strategic assessment of the global status of the fisheries and aquaculture sectors as a baseline of information from which to recommend future USAID program organization;

(2) To recommend to the USAID fisheries and aquaculture activities that foster global economic, social and environmental security, especially activities that integrate fisheries and aquaculture into the comprehensive management of natural and human resources in economically developing nations.

Executive Summary

Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and invaluable providers of employment, cash income, and foreign exchange. Fisheries products are the world's most widely traded foods, with commerce dominated by the developing countries. Fisheries products are the primary protein sources for some 950 million people worldwide, and are an important part of the diet of many more. ***In comparison to other sectors of the world food economy, however, the fisheries and aquaculture sectors are poorly planned, inadequately funded, and neglected by all levels of government. This neglect occurs in a paradoxical situation: fishing is the largest extractive use of wildlife in the world; and aquaculture is the most rapidly growing sector of the global agricultural economy.***

Our vision is one in which the USAID is a world leader in channeling high quality, "needs directed" kinds of technical assistance in fisheries and aquaculture to developing countries, mainly in the form of capacity-building though education and training opportunities, but also in applied research. Considering the status, priority issues and future trends we have identified in this study, we recommend seven strategic approaches and investments to USAID:

1. *USAID needs to substantially increase its programmatic emphasis and enlarge its financial and human resource commitments to global fisheries and aquaculture.*
2. *USAID needs to play a central role in mobilizing America's considerable human and institutional resources in fisheries and aquaculture to assist developing countries.*
3. *USAID needs to bridge the "digital divide" to develop solutions to fisheries and aquaculture issues in developing countries.*
4. *USAID should prioritize the improved management of coastal marine and inland fisheries by providing technical assistance to evolve innovative fisheries management schemes in developing countries, including but not limited to, property rights, co-management, and the use of marine protected areas; plus assist in the development of more accurate and reliable fisheries data reporting systems.*
5. *USAID needs to substantially increase its support to develop more comprehensive, sustainable, ecologically and socially compatible, and economically viable aquaculture systems in developing countries that have the long-term goals of poverty alleviation and food security.*
6. *USAID should prioritize its assistance to fisheries and aquaculture activities that are more integrated, comprehensive, community-based, and use "systems approaches"—such as ecological and integrated farming/fishing systems research and extension approaches—in both rural and urban settings. The current agriculture emphasis of USAID is on plant commodity research, not on comprehensive, agro/aqua-ecosystems research/extension approaches. We urge the USAID to support long-term, applied research and development that makes expanded use of participatory ecological and social science tools to empower community control of fisheries and aquaculture systems; and to better integrate aquaculture and fisheries activities into the comprehensive management of natural and social resources of its missions, target nations and regions.*
7. *USAID needs to develop comprehensive strategic and implementation plans and regular impact assessments of an expanded fisheries and aquaculture portfolio. USAID missions and regions should include fisheries and aquaculture into their strategic plans for the comprehensive management of natural resources—or they will be incomplete—especially in regards to USAID plans for involvement in the issues of water allocation and quality, and plans for the management of marine and inland coastal areas.*

We believe our case for increased strategic engagement and substantially increased investments in priority issues of importance to the future sustainability of global capture fisheries and aquaculture by all levels of the USAID bureaucracy (headquarters, regions, missions, etc.) cannot be overlooked. America has an accelerating trade deficit in fisheries products that now exceeds $9 billion per year—a deficit surpassed only by those in oil and automobiles—and the US remains the 4th largest exporter of fisheries products in the world (~$2.8 billion). The lack of US engagement in international fisheries and aquaculture not only compromises America's financial position: and an important part of our Nation's food security is at risk; and our domestic fisheries and aquaculture industries are rapidly losing their competitive position.

I. Global Environmental Threats to Fisheries and Aquaculture

We live on a human-dominated planet, and the momentum of human population growth, together with the imperative for further economic development in most of the world, ensures that our dominance will increase.[2]

The sustainable development and management of aquaculture and fisheries systems can only occur if these activities are well planned and integrated into the natural and social resource, ecosystems, and farming systems contexts of the larger global context of which they are a part. Population and natural resource constraints in a crowded future demand that aquaculture "fits" as a part of a larger strategy for the non-consumptive, multiple uses of water; and that fisheries be managed sustainably as part of the larger trends affecting the marine environment.

In the past 50 years there has been a massive migration—called the "greatest human migration of all time"—from rural, inland areas to the world's coasts, resulting in about 60% of the Earth's people living within 100 km of the coast.[2] Massive growth of coastal cities has raised issues of the future survival of coastal and estuarine ecosystems and habitats, and has put at risk the livelihoods of millions of people in traditional coastal communities that depend upon the sustainable capture and culture of aquatic living resources. Upwards of 35% of the primary production of the temperate continental shelves is being harvested in fisheries, or discarded back to the sea as waste ("bycatch"). Coastal margins and oceans are among the most heavily used and modified areas of the planet, suffering disproportionate amounts of habitat destruction and pollution. Humans have removed about 50% of the world's mangroves. Human activities in the coastal zone deliver sewage, solid wastes, refuse (marine debris), sediments, dust, pesticides, and oil hydrocarbons to rivers, estuaries, and coastal areas. Assessing the range, magnitude and delivery of land-based sources of pollution to coastal oceans is a major global effort. It is estimated that about 80% of marine pollution originates from land-based sources and activities.[2] Inputs of nutrients to the coastal zone from development and agriculture have caused an increase in toxic algae blooms, some of which have caused human disease and neurological impairment. In Shanghai, China, an estimated 13,000 factories discharged 10.55 million tons of waste in 1989, nearly twice the amount in 1980; about one-fifth was toxic waste. The Songhua River in China contains 10 tons of mercury and has waterborne mercury concentrations higher than those reported after the disaster in Minamata Bay, Japan. About one-third of China's coastal waters are polluted with oil; mercury and cadmium have been detected in 60% and 33% of seawater samples, respectively.[3] In Poland, 92% of the nation's rivers are "beyond classification", meaning that the level of pollution is greater than that described by any existing pollution category.

Humanity is the now one of the major driving forces in the Earth's hydrological cycle, using more than half of the world's freshwater runoff.[2] Agricultural water use accounts for about 75% of total global consumption, mainly through crop irrigation, while industrial use accounts for about 20%, and the remaining 5% is used for domestic purposes. Most of the world's rivers are dammed—there are 36,000 dams—and the number of dams is increasing.[4,5] Many major rivers (Colorado, Nile and Ganges) are so heavily used that little or no water reaches their deltas and the sea. Only 2% of rivers in the USA run free. Major inland water areas (Aral Sea, Lake Chad, etc.) have nearly dried up or been greatly reduced to small lakes. It is estimated that two out of every three people will live in water-stressed areas by the year 2025. In Africa, it is estimated that 25 countries will be experiencing water stress (below 1,700 m^3 per capita per year) by 2025. About 450 million people in 29 countries suffer from water shortages.[5] Clean water supplies and sanitation are major problems in many parts of the world, with 20% of the global population lacking access to safe drinking water. Water-borne diseases from fecal pollution of surface waters are a major cause of illness in developing countries. Polluted water is estimated to affect the health of 1.2 billion people, and contributes to the death of 15 million children annually.[5]

Losses of biodiversity are occurring at alarming rates. Rates of loss are estimated at 100—1000 times greater than natural rates of extinctions. Extinction rates are even higher on remote islands, such as Hawai'i, USA. Due to the ease and rapidity of global transportation, the world's ecosystems are becoming "homogenized" due to "biological invasions": the exotic introductions of plants and animals, bacteria and other pests to natal ecosystems. After land transformations, exotic species impacts are the second major cause of species extinctions and population losses. About 11% of birds, 18% of mammals, 5% of fish and 8% of the Earth's plants are threatened with extinction, and exotic species have contributed greatly to their demise.

Given these immense global challenges, Vitousek et al.[2] recommend:

- A slowing the rate of population growth since humanity's growth drives all resource use and waste generation,

- A reduction in the rate of human impacts since ecosystems can react to lower rates of impacts and stabilize with moderate levels of human-induced changes,

- Accelerating ecosystem level research and management understanding. Human impacts must be included in all analyses of global and ecosystem change. Ecological science must include development of new methodologies to assist humanity in this global crisis, requiring development of true interdisciplinary environmental scholarship, and education of the "informed generalist."

II. The Global Importance of Fisheries and Aquaculture

Fisheries play an important role in the world food economy. Fisheries are a source of employment for about 200 million people who depend directly upon ocean fishing for their livelihoods.[6] Fish is the primary source of protein for some 950 million people worldwide and represents an important part of the diet of many more.[6] In less than 50 years, the world's average per capita consumption of fish has almost doubled.[7] Globally, fish provide about 16% of the animal protein consumed by humans, and are a valuable source of minerals and essential fatty acids.[8] Fish is the primary source of omega-3 fatty acids in the human diet. Omega-3 fatty acids are critical nutrients for normal brain and eye development of infants, and have preventative roles in a number of human illnesses, such as cardiovascular disease, lupus, depression and other mental illnesses.[9]

The reported production of fish for direct human consumption doubled between 1950 and 1970, and has stabilized since then at an average of 9.0 to 10 kg of fish per capita, notwithstanding world population growth.[10] Fish consumption per person is expected to continue to rise. Supply will probably be limited by environmental factors, and a likely range for demand is 150 to 160 million tons, or between 19 and 20 kg per person in 2030.[7] Global increases in consumption of food fish will take place predominantly in the developing countries, where population is growing and higher incomes are allowing purchase of high value fisheries items for the first time by many people.[11] However, fish production in least developed countries where fish protein is needed to prevent malnutrition is a key element of food security in these regions and a critical area where innovative programs are needed to increase production.

Today, fishing is the largest extractive use of wildlife in the world.[7] The value of world total fishery production in 1999 was US$ 125 billion.[12] World production of fish, crustaceans, mollusks and plants reached 142 million tons in 2001. Capture fisheries production, which accounted for 66% of the total, was 93.7 million tons, of which inland capture was 8.7 million tons, while aquaculture production was 48.4 million tons including plants. Marine and freshwater fish are also an increasingly important recreational resource, both for active users such as anglers and for passive users such as tourists, sports divers and nature-lovers.[13]

Asia predominates in capture fisheries and aquaculture production **(Figure 1)**, with China the leading nation worldwide. In 1999, over three-quarters (or 97 million tons) of the global production of fish, crustaceans and mollusks were utilized for direct human consumption. Fish utilized as raw material for the production of animal feed, e.g., fish meal and fish oil, represented about one-quarter of the total fishery production in 1999; and this amount has remained relatively static for the past 15 years.[14] Most growth in the fisheries sectors is projected to occur in developing countries, which will account for 79% of food fish production in 2020.[11]

Increased production of fish from aquaculture has occurred primarily as a result of increasing feed inputs into ponds and other production systems, thereby increasing yields per hectare by an order of magnitude compared to extensive production systems in which rearing water is fertilized only. Higher inputs mean two things to the aquaculture feed industry; more feed and higher quality feed. Currently, global feed production for farmed fish and crustaceans is approximately 13 million tons, and predictions are for feed production to increase to over 37 million tons by the end of the decade[15], an increase of 24 million tons. Feeds for salmonids and marine fish have always been complete feeds, i.e., ones that supply all of the nutritional needs of the fish. Pond-reared fish, in contrast, obtain a significant proportion of their nutritional needs from pond biota. The degree to which feeds must supply essential nutrients to pond-reared fish increases as rearing densities increase beyond the capacity of natural foods in ponds to supply them. Fish farmers around the world have found that as they increase feed inputs, the biomass and economic yields from ponds increase as well. Thus, great areas of low-input, pond-based aquaculture mainly in Southeast Asia and China are being converted from low-input systems to high-input systems that depend upon high quality feeds to supply an increasing proportion of nutrients used by the fish.

The effects of the aquaculture industry's growth and of changes in feed input in pond-based aquaculture have been dramatic with respect to the use of marine proteins by the aquaculture feed industry. In the mid-1980s, less than 10% of annual fish meal production was used by the aquaculture feed sector. Today, that proportion is over 40%.[16] Similarly, aquaculture now uses nearly 75% of annual global fish oil production, up from less than 10% seventeen years ago, but this change is mainly due to the adoption of high lipid feeds by the salmon farming industry, rather than increasing the inputs into pond-based aquaculture systems. Fish meal and oil are produced from species of fish that are not generally utilized directly for human food, e.g., herring and capelin in Norway and Iceland, sand eel in Denmark, capelin in South Africa, anchovies in Peru and northern Chile, jack mackerel in central Chile, sardines in Japan, and menhaden in the USA. The rapid increase in fish meal and oil use in aquaculture feeds over the past 15 years has not resulted in over-exploitation of the stocks of fish harvested primarily to produce fish meal and oil. Production of fish meal has averaged between 6-7 million tons per year since the mid-1980s, except in El Nino years, when production has been lower. Fish oil production has averaged between 1.2-1.3 million tons. No significant changes in annual harvest or fish meal/oil production associated with increased aquaculture production or increasing intensification of aquaculture and concomitant higher feed inputs is evident. Increased fish meal/oil use in the aquaculture sector has come at the expense of other uses.

Estimates of future protein requirements for aquaculture feeds depend upon future production from various segments of the aquaculture industry and on annual production levels of fish meal. As aquaculture production expands, it will be essential to replace portions of fish meal and oil in fish feed formulations with alternative ingredients derived from alternative sources, primarily grains and oilseed products **(Appendix 1)**.

Because 70% of the fish meal used in diets for fish and crustaceans is used to produce diets for salmonids, marine fish and shrimp, these production sectors are the focus of most research with respect to the use of alternative protein sources. Numerous studies have been conducted to evaluate the effects of replacing various percentages of fish meal in diets for these fish, and, without exception, none has successfully replaced 100% of fish meal without reducing fish performance. At best, 50% of fish meal in diets for salmon and trout can be replaced by soy protein concentrate, and 25-30% with soybean meal.[17-20]. Similar findings have been reported in studies of wheat gluten meal, corn gluten meal, and rapeseed protein concentrate.[21,22] For the most part, formulated fish diets are used to produce high-value fish for export. In underdeveloped countries, increased production of lower-value fish that are consumed by local populations will depend upon the use locally-available, low-cost feed ingredients that can be combined to produce prepared feeds to increase productivity of community ponds and waterways.

This is an area that requires substantial investigation and development, and is a logical target for USAID support. Another logical target for USAID efforts is the development and testing of feeds that are based upon sustainable plant-derived protein sources for use in developing countries where fish are grown both for domestic consumption and export, such as China. Partnerships with US commodity groups could be a mechanism to extend USAID efforts. It is critical that USAID become a leader in this area, given the perception that increased aquaculture production leads to higher fish meal use and greater pressure on stocks of fish that are captured to produce fish meals and oils.

Fisheries products have become the most internationally traded food, as some 37% (by quantity) of all fish for human consumption is traded across borders.[11] In 1999, international trade (in live weight equivalent) represented 34% of the total production. In 1999, foreign trade earnings amounted to US$ 52.9 billion.[11] Most fishery exports were destined to developed countries, with Japan the world's leading importer, and the USA second. The US balance of trade deficit in seafood products is approximately $9 billion. Exports of fisheries products to the developed countries have become so lucrative that nations like Argentina, a traditional, globally important exporter of meat products and livestock have turned to seafood exports as the major source of foreign exchange earnings. In 2002, exports of raw and processed fish and shellfish from Argentina surpassed meat products and livestock, with beef earning US$ 574 million in export revenue, while seafood—mostly prepared products—earned US$ 714 million. Argentina's main consumers of domestic seafood products were Spain, Brazil and the US.[23]

III. Status, Trends and Issues in Fisheries and Aquaculture

We suspect that living in true harmony with the natural world, in a manner sustainable over the long run, is something no modern human society has yet learned how to do. The survival of the natural world, however, and likely our survival as a species, depends on our learning to do this. It will be a unique experience in human history.[24]

Marine Fisheries Resources and Potential

Reported global production of marine capture fisheries increased from 17 million tons in 1950 to about 80 million tons in the mid-1980s, oscillating since then between 78 and 88 million tons (excluding discards) **(Figure 2)**, representing 60% of the overall fisheries production including aquaculture in 2001. The annual rate of increase of marine catches decreased to almost zero in the 1990s, indicating that the world oceans have reached their maximal production under the present fishing regime.[10]

An estimated 25% of the major marine fish stocks for which information is available are underexploited or moderately exploited. Stocks or species groups in this category represent the main source for the potential expansion of total marine catches. About 47% of the main stocks or species groups are fully exploited and are therefore producing catches that have reached, or are very close to, their maximum sustainable limits. Thus, nearly half of world marine stocks offer no reasonable expectations for further expansion.

Another 18% of stocks or species groups are reported as overexploited. Prospects for expansion or increased production from these stocks are negligible; and there is an increasing likelihood that stocks will decline further and catches will decrease, unless remedial management action is taken to reduce overfishing. The remaining 10% of stocks have become significantly depleted, or are recovering from depletion and are far less productive than they used to be (or than they could be) if management can return them to the higher abundance levels commensurate with their pre-depletion catch levels. Recovery usually implies drastic and long-lasting reductions in fishing pressure and/or the adoption of other management measures to remove conditions that contributed to the stock's overexploitation and depletion.[25] In most areas, overfishing is certainly a significant factor responsible for the declines.[10] The information available tends to confirm the estimates made by FAO in the early seventies that the global potential for marine fisheries is about 100 million tons of which only 80 million tons were probably achievable for practical reasons. It also confirms that despite local differences, overall, this limit has been reached.[10]

Developed countries are faced with fully or overexploited stocks so their management objectives concentrate on stock rebuilding and capacity reduction, although most countries also have significant aims regarding markets and social conflict. The most urgent objective is to scale fleet sizes so that they become commensurate with sustainable exploitation of the resources. Management plans also increasingly recognize the need for a policy that integrates fisheries with management of the coastal zone or inland waters.[26]

Developing countries tend to concentrate on fisheries development in terms of new resources and technology. Although it is recognized that some stocks are overfished, objectives are concentrated more on enhancing and diversifying fisheries rather than on limiting fishing efforts. This is perhaps because the underlying concern for many countries is the relatively important role fisheries play in employment and food security for some of their poorest people. More specific aims include building infrastructure (particularly for processing to reduce post-harvest losses and increase the value added); fishery enhancement, through restocking; and reducing social conflicts, not only among different fishing groups but also between fisheries and other sectors.[27]

The principal policy challenge is to bring the capacity of the global fishing fleet back to a level at which fish stocks can be sustainably harvested. Fisheries based on clearly defined rights of access will need to become more common: experience shows that when these rights are not merely in place but are understood and observed by users, conflicts tend to be minimized.[10] The need is to blend innovation, research, conservation and educational awareness into a goal of aquatic sustainability, and to demonstrate this via successful commercial enterprises.

The "great trends" of the past 20 years in marine fisheries worldwide are the: (1) globalization of both production and labor in marine fisheries, (2) the overcapacity of fleets both nearshore and offshore, resulting in dramatic and widespread declines in catches per unit efforts, (3) the movement of the bulk of the world's fishing capacity from the developed to developing countries, resulting in (4) declining catches and economic hardships worldwide in small scale artesanal and inshore fisheries resulting in less fish for poor consumers, and (5) infant success with various property rights schemes and use of protected areas to sustain stocks **(Appendix 2)**.

Inland Fisheries Resources and Potential

Four current strategies in the use of inland waters for fisheries can be distinguished: (1) food fisheries based on wild stocks; (2) enhancement of food fisheries in smaller water bodies and reservoirs; (3) recreational fisheries, which are becoming more common in many areas of the world, and, where they develop, tend to supplant commercial food fisheries; and (4) locally very intense exploitation of juvenile or small adults for stocking into other water bodies and/or aquaculture ponds, or for the ornamental fish trade.[28]

In 2001, inland capture from 129 countries[29] reached 8.7 million tons **(Figure 3)**. Regionally, Asia dominates inland capture, accounting for nearly 66% (about 5.8 million tons) of the total in 2001, with Africa second at 24% (nearly 2 million tons). In comparison, the remaining regions are relatively insignificant. The capture from inland waters is very diverse. Apart from fish, other groups included in inland capture that are tabulated by weight are freshwater shrimps and prawns, frogs, terrapins, turtles, crayfishes, mussels, mussel shells, pearl oyster shells, swamp crabs, marine worms, manatees and green seaweeds.[30]

There is an enigma concerning the status of inland fishery resources. On the one hand, it is widely accepted and well documented that freshwater resources and environments are deteriorating rapidly and widely. On the other hand, harvests from freshwater environments are stable or on the upswing among countries that account for 93% of the total inland capture. The increases are due to two factors: (1) enrichment of aquatic systems from land based human activities that until now have been a counterweight to habitat losses and pollution; (2) enhancements of inland fisheries (e.g., stocking, introductions) that increase the output per unit of area; and (3) the increased number of reservoirs with capture fisheries enhancement activities.[31] Inland fisheries enhancement methods, often combined with conventional fisheries management practices, are widely applied, and are becoming a central theme in the management of inland waters in developing countries The exact contribution of enhancements to the total inland capture fisheries production is, however, difficult to estimate.

About two-thirds of inland capture is from developing countries and about one-fourth is from China **(Figure 4)**. The countries in Africa and Asia that are among the top 20 in inland capture production also rank low in the Human Development Indices. This comparison underlines the need to sustain inland fisheries in the countries where inland capture is relatively important in its own right, where inland capture contributes significantly to food security, and where levels of human development are lowest.[30] In contrast, inland recreational fisheries are pre-eminent in most developed countries; however, almost every country with inland waters has some recreational fisheries that often play an important role in subsistence. Indications are that freshwater recreational effort is perhaps one-half of the food fishing effort from a worldwide perspective.[31]

Output from inland food fisheries will continue to increase slowly overall. In the short term most of the gains will be realized where enhancements are already common, namely in Asia. In Africa, where enhancements have been slow to be implemented, output may actually decrease due to overfishing and a deteriorating environment in the most populous countries, but increase as enhancements become more widely implemented. Likewise, in Latin America, inland fisheries enhancements are practiced and are growing, but the demand for inland fish is weak in many countries, while in others degradation of the environment is causing a decline in production.

Degradation of the environment is the main underlying issue, and the consequent loss of fishery habitat is the pre-eminent concern. A closely related concern is that loss of habitat that, along with the intense and widespread exploitation of fishery resources, negatively impacts aquatic biodiversity. In practical terms, the resiliency of resources to fishing, and often the quality of the resources, is lessened.[31] Additionally, in most countries the main challenges to maintaining and enhancing inland fish production and small-scale aquaculture and their associated social and economic benefits are increasing competition for resources and insufficient institutional and political recognition.[26]

Reporting and Statistical Issues in Fisheries

Without reliable statistics, effective fisheries management and policy-making are impossible. During the last decade, financial support for the development and maintenance of national fishery statistical systems have decreased sharply in real terms, while statistical requirements have been increasing dramatically for by-catch and discards, fishing capacity, illegal fishing, vessels authorized to fish in the high seas, economic data (costs, revenues, prices, subsidies), employment, management systems, inventories of stocks and fisheries, aquaculture, etc. Despite FAO's efforts, the available fisheries data are not fully reliable. The outcome is far from perfect in terms of coverage, timeliness, and quality. Statistics from artisanal and subsistence fisheries are still a concern, and many key statistics are missing, e.g. economic and social data, discards, fishing capacity, etc. The result is that the general trends are probably reliably reflected, but the annual figures and the assessments involve a degree of uncertainty, and small changes from year to year are probably not statistically significant. Illegal, unreported and unregulated fishing is found in all capture fisheries, irrespective of the location, species targeted, fishing gears employed or level and intensity of exploitation.[32] Working with the countries is the only way to improve fishery statistics, primarily to meet national needs with regard to food security and fisheries management.[33] Unlike capture fisheries, the separate monitoring of aquaculture is relatively new in most countries, and often there are less well-established systems of data collection as compared to capture fisheries.[34]

Actual inland capture fisheries production is considerably greater than the amounts reported to FAO. The factor is at least two overall, but may be as high as three in some instances. There is an urgent need for better data on inland fisheries that can be interpreted in both economic and ecological terms. Although the cost of improving inland fishery data collection may be high, failure to fully account for inland capture also is costly in terms of lost opportunities to increase food security and other economic and social benefits from enhanced management of inland fisheries resources.[35]

A recent article in *Nature*[36] indicated that China's marine capture fishery production for 1995-1999 has been overstated in Chinese statistics submitted to and published by FAO. The paper states that as a consequence of this, global marine capture fishery production—excluding Peruvian anchoveta—has likely been declining since 1988 rather than remaining fairly constant as indicated by the statistics. According to the authors, this would have led to understating the degradation of world fisheries, and produced unfortunate policy and investment decisions. However, the FAO maintains that despite likely errors in the data sets, the main global trends have not been masked, and that the most important conclusions have emerged, nevertheless. These findings, together with similar ones emerging at regional and national level, have been the foundation for the governance and institutional changes observed since 1990.[37]

Aquaculture Status and Potential

Aquaculture is more akin to farming and animal husbandry than to fishing, as it involves the rearing and management of living aquatic resources in a restricted environment. Tenure of production facilities, and property rights to the produce, are as important to the success of aquaculture as land tenure is to agriculture.[30] *Aquaculture has been developed to serve a variety of purposes: (1) producing high nutritional value food for human consumption; (2) contributing to rural income and employment through farming and related activities; (3) enhancing capture and sport fisheries; (4) cultivating ornamental species for aesthetic purposes; (5) controlling aquatic weeds or pests hazardous to humans or crops; and (6) desalination and other forms of soil recuperation.*[38]

Meeting basic human needs for protein foods in the future will be a difficult challenge. Approximately 1.3 billion people live on less than a dollar a day—the cost of a half a pint of beer—and half of the world's population lives on less than 2 dollars a day.[39] Since 1950, there's been a 100% increase in the per capita demand for fish, a 40% increase for grain, and 33% for wood. If world fish consumption will increase from 16 kg (1997) to 19-20 kg by 2030, total human use of aquatic foods will increase to 150-160 million tons. Capture fisheries can provide no more than 100 million tons, so the bulk of the increase will need to come from aquaculture.

In 2001, 48.4 million tons of aquatic products (including plants) valued at US$ 61.5 billion were produced, with half of the production being finfish **(Figure 5)**. Aquaculture is growing more rapidly than all other animal food producing sectors. Worldwide, the sector has increased at an average compounded rate of 9.2% per year since 1970, compared with only 1.4% for capture fisheries and 2.8% for terrestrial farmed meat production systems.[30] Over half of global aquaculture production originated from marine and brackish coastal waters, while the remainder (45%) was from freshwater **(Figure 6)**.

Aquaculture will soon overtake cattle ranching as a global food resource, possibly signaling a basic shift in diets. Over the last century, the world relied heavily on two natural systems—oceanic fisheries and rangelands—to satisfy a growing demand for animal protein, but that era is ending as both systems are reaching their productive limits. Between 1950 and 1990, beef production, four-fifths of it from rangelands, nearly tripled, climbing from 19 million to 53 million tons before leveling off. Since 1990, there has been little growth in either beef production or the oceanic fish catch. Additional production of beef or seafood now depends on placing more cattle in feedlots or more fish in ponds.

Comparisons of energy and production efficiencies of aquaculture versus a array of fisheries and terrestrial agriculture systems confirm that aquaculture is an efficient mass producer of animal proteins for a crowded, coastal planet.[40] Production efficiencies of edible mass for aquaculture range from 2.5 to 4.5 kg dry feed/kg edible mass compared with 3.0 to 17.4 for conventional terrestrial animal production systems. Beef cattle require over 10 kg of feed to add 1 kg of edible weight, whereas catfish can add a kg of edible weight with less than 3 kg of feed. To produce 1 kcal of catfish protein about 34 kcal of fossil fuel energy is required—lobster and shrimp capture fisheries use more than 5 times this amount of energy. Energy costs for even the most intensive salmon cages are less than lobster and shrimp fishing, but are comparable to beef production in feedlots.[40] Aquaculture also has a comparable advantage in water efficiency, since a comparatively smaller amount of water for aquaculture is required. For example, catfish ponds managed using multiple harvest strategies use 1.50 m^3 of water per 1 kg of product while conventional soybean production takes 1.63 m^3 of water to produce 1 kg.[40]

In a world of land and water scarcity, the advantages of aquaculture over capture fisheries and other land-based protein production systems to produce low-cost animal protein are clear. However, care must be taken to ensure that aquaculture is not viewed as a panacea—since most analysts agree that aquaculture will never completely replace capture fisheries—and that increased aquaculture production will not be associated with higher rates of environmental damage and harvest rates of forage fish species used to produce fish meals and oils, which would lead to a net loss of fish production (e.g. the capture for fish meals and oils would exceed the amount of fish produced for consumption).

There are many cases where aquaculture expansion has fueled the hope of fragile coastal and inland rural communities that have undergone unprecedented changes in their traditional ways of life. Aquaculture has provided significant multiplier effects on the local economies increasing both direct and indirect personal spending in these coastal communities. And yet, communities in many parts of the world actively oppose aquacultural development because such development is perceived as a threat to local social and/or ecological systems. If intensive aquaculture operations—no matter how advanced technically—have no community roots; and feeds, seeds, supplies, equipment and human expertise are procured from great distances from the sites of production; community opposition will continue to occur. In these cases it is easy to see why some community members view aquaculture development as "all we get is your pollution". Planning for aquaculture development as community development and environmental enhancement must thereby encompass regional planning processes to accommodate aquaculture's vital support industries (inputs), and for the use of aquaculture resources and wastes in agriculture or in environmental enhancement projects (outputs). Regional planning for “ecological aquaculture” developments will have much higher positive impacts on jobs and the environment, and will eventually dissolve the opposition from communities who will see the newcomers as one of their own.[40]

Aquaculture production systems, aquatic environments, and the feeds to produce fish must be environmentally benign and ecologically sound in order for the advantages of aquaculture as a food production system to be embraced and supported. Indeed, the expansion of aquaculture can never be justified on the destruction of the world’s capture fisheries. The future protein needs of millions of people—and the sustainability of aquaculture itself—depend on the conservation, good management and recovery of the world’s capture fisheries and the environments on which they depend.

IV. Indicative Needs for Applied Research and Development

The Code of Conduct For Responsible Fisheries[41] can be viewed as a statement of the broad issues in the fisheries sector. Likewise, the FAO Technical Guidelines for Responsible Fisheries[42] can be seen as road maps to resolving the issues, e.g., No. 8. Indicators for Sustainable Development of Marine Capture Fisheries, No. 9, Aquaculture; No. 6 Inland Fisheries; No. 3 Integration of Fisheries into Coastal Area Management. Similarly, the fisheries and environment parts of the World Summit can be considered as a shopping list of issues still outstanding.[43] Close examination of these research and policy documents allow us to point out the consensus of many experts and policy makers regarding the following major indicative needs for global fisheries and aquaculture.

Marine Fisheries

The marine capture fisheries of developing countries are vital for food security, but environmental destruction and the unsustainable rate of extraction are mining their future potentials.

The rapid growth in human knowledge of marine ecosystems and their response to human actions over the last few decades cannot disguise the fact that our understanding of these systems is still fragmentary. Fishery development must therefore be closely linked to research programs on environmental preservation. To date, the demand for research has tended only to follow stock depletion and environmental degradation instead of being precautionary.[10,44] In comparison to the long-standing emphasis on technical investments in fisheries, comparably little attention has been paid to the users of fishery resources. This is despite the fact that the socio-economic problems confronting users are the main factors leading to the over-exploitation of the resources and, ultimately, to the success or failure of fisheries management and development. A further problem is that fishery researchers often have a low status and income in a given national context, have limited facilities and resources, opportunities for in-service training, and have limited access to outside scientific research information.[44]

Capture fisheries suffer from overexplotation, overcapacity, wasteful by-catch and destructive fishing practices that damage aquatic ecosystems, aquatic food webs and critical habitats, reducing production. The Study on International Fishery Research (SIFR)[45] identified four broad areas of research in marine fisheries that, if undertaken at the national level, would facilitate the link to international (regional) co-operative research that allow the possibility of sharing expensive equipment and facilities. These four areas are:

1. Resource conservation and management: management of environmental influences on fishery production, the environmental impact of fishery activities (including effects on human health), the conservation of ecosystems and genetic diversity and the management and sustainable exploitation of marine resources;

2. Fish productivity: the use of aquaculture to enhance fishery resources;

3. Fish commodity conversion and utilization: all aspects of the conversion of a fishery resource into food: capture, fish handling; processing and marketing, on post-harvest technology, particularly quality control, marketing and consumer protection;

4. Human linkages: the relationships between people and the marine resources they use, the socio-economic aspects of fishing communities, access to resources, the incorporation of coastal fisheries into integrated coastal area management schemes and fishery policy development.

Although marine resource management should be based on the best scientific evidence available, it also requires governmental and local coastal infrastructure, systems of information diffusion and consultation between parties concerned.[44]

Inland Fisheries

Broadly, the main need in inland fisheries is to sustain the productivity of aquatic environments through integration with other non-degrading uses of water. The priority technical areas of applied research and development for inland capture fisheries interventions are: rehabilitation of inland fish habitats; integrated floodplain fisheries development; restoration and enhancement of reservoir fisheries; and genetic resources management.[28, 31]

Aquaculture

Aquaculture is an ancient practice but until the 1950's depended less on innovations arising from applied science and directed management skills than on accomplishments derived from trial and error. Of the 25,000 fish species only a few are harvested for direct human consumption. Aquaculture science is still poorly developed (and funded). There are very few centers of excellence in aquaculture, and few aquaculture experiment stations. Clearly, aquaculture is the "poor cousin" of agriculture and capture fisheries.

Most scientific inquiry in aquaculture is "discipline-oriented", e.g. organized in a traditional, compartmentalized manner in major academic centers. Multidisciplinary aquaculture scientists—which David Orr[46] has called "specialists in whole things"—are rare. To develop aquaculture more sustainably, aquaculture science needs to break through disciplinary bounds and tie together real-world knowledge and academic disciplines and create a new, knowledge-based infrastructure and support system. Aquaculture needs a true interdisciplinary environmental scholarship to evolve—much like the field of oceanography. Lubchenco[47] calls for a "new social contract for science" which would "facilitate the investigation of complex, interdisciplinary problems that span multiple spatial and temporal scales; to encourage interagency and international cooperation on societal problems; and to construct more effective bridges between policy, management, and science, as well as between the public and private sectors. Lubchenco states that, "Most of our efforts to address economic and social problems are as yet devoid of ecological knowledge."

Aquaculture faces a number of problems, including access to appropriate technologies, lack of comprehensive, inter-sectoral planning, a lack of financial resources for the poor, environmental impacts and diseases. The priority areas for further research include[25, 40,48—52]: land, water and feed/nutrient use in aquaculture; sustainable intensification of freshwater aquaculture production; an ecosystems approach to comprehensive integrated aquaculture-agriculture in rural development; sustainable coastal aquaculture development; the adoption of aquaculture by poor rural households; technologies for sustainable stock enhancement, ranching programs, and open ocean aquaculture; the use of aquatic plants and animals for nutrient stripping; managing the health of aquatic animals; low cost and alternative, non-fish meal based feeds; the quality and safety of aquaculture products; emerging technologies, including recirculating systems, offshore cage culture, artificial upwelling and ecosystem food web management, and domestication and selective breeding and genetic improvement.

Environmental concerns will likely shift the focus of aquaculture away from coastal zones into more intensive inland systems. Marine ranching will also expand, though its long-term future will depend on solutions to the problems of ownership surrounding released animals. At present, only Japan is engaged in sea ranching on a large scale[10], but large salmon enhancements efforts exist in Alaska[53], and other temperate areas.

A key aspect of the future of aquaculture is that China's role in world fisheries issues cannot be ignored. Even allowing for large margins of error, it is clear that the rate of continued aquaculture development in China and it diffusion to other developing countries are the key variables affecting fisheries.[11]

A poverty focus would suggest concentrating on aquaculture in developing countries that produce low value food fish. However, the rosy outlook for high value aquaculture items such as crustaceans and mollusks in developing country urban markets also suggests the importance of finding ways to keep poor fishers involved in these key sectors.[11] While export-oriented, industrial and commercial aquaculture practices bring much-needed foreign exchange, revenue and employment, more extensive forms of aquaculture benefit the livelihoods of the poor through improved food supply, reduced vulnerability, employment, and increased income.[54]

A large mainly unrealized potential for inland fish farming has been indicated for Latin America by using GIS and remote sensing.[55] Both commercial and small-scale fish farming are possible over vast areas without serious constraints, either from the lack of suitability of basic factors that are important for development and operation of fish farms, or from constraints of temperature on fish growth. Similar promising results were obtained for Africa.[56]

The rapid growth in aquaculture production has made the sector important to the economy of many developing countries and, in the case of some traded aquatic products, the sector has become either an important source of supply or the main supplier. In these cases, fluctuation in production of farmed products has significant impact on price trends. In general, however, aquaculture products have helped to stabilize supplies of traded products and to bring down prices over the years.[57]

V. Needs for Enhanced Management & Extension Capabilities

Human resource development and institutional strengthening are widely held to be the principal requirements for improving integration at the level of individual farms and communities, in river basin and coastal area management, and at the level of sectoral and macroeconomic policies.[43] Co-management and community-based management approaches to the use of common-property resources have received increasing attention in recent years because of their assumed greater efficiency and prevention of undesired distributional implications. Land use planning and zoning, together with environmental impact assessment procedures, are vital tools for minimizing conflicts between resource users, negative environmental impacts and enhancing sustainable development. The involvement of fisheries agencies in these activities therefore is clearly essential.[43] Factors that the users themselves identify as being important for successful resource management include: small group size (which facilitates the formulation, observance and monitoring of a collective agreement), social cohesion, resource characteristics that facilitate the exclusion of outsiders, and visible signs of successful collective management. At the level of river basins and coastal areas, integration is aimed at managing components as parts of a functional whole, explicitly recognizing that management needs to focus on human behavior, not physical stocks of natural resources such as fish, land or water.[43]

Technical adaptations alone are inadequate to direct sustainability of complex enterprises such as aquaculture and fisheries. An improved, and more participatory, applied research process can stimulate a greater momentum for change and increase the effectiveness of aquaculture/fisheries extension approaches. In order to ensure the ecological and social sustainability of fisheries and aquaculture systems, new methodologies must become more widely available to capture both the global (macro) and the fishing/farm-level (micro) social ecological processes occurring in order to determine the appropriate paths for research and extension interventions. As an example of what is required, the USAID Pond Dynamics/Aquaculture CRSP conducted groundbreaking micro-economic analyses of markets in Central America which provided invaluable data to support decision-making on pond aquaculture facilities. Such efforts need greater emphasis and need to be expanded to include analyses of nearshore and inland capture fisheries issues. In addition, much more attention needs to be given to marketing and market development issues. Small scale fishers and farmers in developing countries require additional education and training to help them determine markets capacities for their products. Larger producers need additional education and technical assistance with marketing plans that include basic information on market networks.

Participatory technology development (PTD), pioneered by the workers in the fields of farming systems research and extension and agroecology **(Appendix 3)**, has been found to be a very successful approach when applied to enhance the sustainability of fisheries and aquaculture farming systems.[40] PTD has been called "participatory learning for action". PTD uses assessment tools to enable fishers and farmers to analyze their own social ecological situation and to develop a common perspective on natural resources management and fisheries/food production at the local level. PTD involves group facilitation methods, methods for interviewing and dialogue, and visualization/diagramming methods. In farming and fishing systems PTD approaches the natural and social ecological sciences come together in a very unique form of interdisciplinary environmental scholarship. Fixed answers derived from fisheries/agriculture/aquaculture experiment stations and passed down to farmers in a top-down manner are too inflexible and cannot solve the problems of sustainability which require more site specific, integrated social and ecological methodologies. Aquaculture farmers and coastal fishers are innovative groups in their communities, and farmers/fishers oftentimes know as much as researchers—making the reversal of traditional extension roles a given which should be embraced as a set of unique opportunities for collaborative work—not challenged or fought. By initiating a new era of cooperative research with fishers/farmers, a more detailed and very intimate knowledge of the natural and social ecology of farming/fishing systems can be combined with useful scientific knowledge to evolve sustainable aquaculture and fisheries ecosystems.[40]

VI. Summary and Recommendations

Clearly, the needs and capabilities of developing countries in fisheries vary widely. In this report we have identified the main strategic issues and trends in fisheries and aquaculture from a global perspective. The strategy that we advocate for USAID is to identify and address the common needs within and among countries to benefit the greatest number of people for the resources available.

Considering the issues and future trends we have identified in this study, we recommend the following strategic approaches to USAID:

1. ***USAID needs to substantially increase its programmatic emphasis and enlarge its financial and human resource commitments to global fisheries and aquaculture.***

Given the importance of fish and fisheries to the global economy and their importance in poverty alleviation and food security, USAID has ample justification to increase its global profile in fisheries and aquaculture. We strongly recommend that USAID substantially increase its programmatic emphasis, funding, and enlarge its staff commitments to global fisheries and aquaculture issues. If USAID cannot increase its core commitments in these areas, the Agency should consider augmenting its core staff by rotating into USAID mid- and senior level professionals from state and federal governments, academia, NGOs, and industry.

USAID needs to make more prominent the importance it gives to the sustainability of fisheries and aquaculture at all levels of its bureaucracy: at its DC headquarters, and in all of its missions, and its regions. In addition, USAID needs to give a higher profile to capture fisheries and aquaculture issues in descriptions of its overall agriculture and natural resources portfolios. We find the word “fisheries” missing from these; and we believe aquaculture is too “buried” in lists describing a wide range of agricultural issues that interest the USAID.

2. ***USAID needs to play a central role in mobilizing America’s considerable human and institutional resources in fisheries and aquaculture to assist developing countries.***

Our vision is one in which the USAID is a world leader in channeling high quality, “needs directed” kinds of technical assistance in fisheries and aquaculture to developing countries, mainly in the form of capacity building though education and training opportunities, but also in applied research. In order to achieve this vision, we believe that the USA needs to increase its competence and competitive position in dealing with fisheries and aquaculture issues in developing countries.

USAID needs to play a central role in mobilizing America’s considerable human and institutional resources in fisheries and aquaculture to assist developing countries. This can be brought about by a variety of initiatives, but the basic requirement is for US applied science and outreach professionals to work more often and for longer durations in developing country fisheries and aquaculture situations in a way that focuses more closely on collaborative solutions to common issues. A key element of USAID approaches must be the leveraging its organizational and leadership strengths in fisheries and aquaculture by utilizing the considerable array of expertise and talent that exists in America's government (USDA, NOAA-OAR, NOAA-Sea Grant, NOAA-Fisheries, USGS, etc.), universities, state agencies, industry, and NGOs. We encourage USAID to develop innovative ideas/proposals to link with the interests of the US State Department and the Peace Corps to develop additional policy, research, and extension capabilities. In addition, the USAID needs to better insure that its multi-lateral and bilateral investments make the most use of American expertise in fisheries and aquaculture, especially in regards to instruments and relationships with The World Fish Center, various UN organizations, The World Bank, and The Asian, African, and Interamerican Development Banks.

The Pond Dynamics/Aquaculture CRSP (PD/A CRSP) is one notable example of how the USAID can play an enhanced role in mobilizing America's considerable human and institutional resources in fisheries and aquaculture to assist developing countries. The PD/A CRSP has been involved with over 50 institutions and NGOs in 27 host countries. Since the inception of the PD/A CRSP over 200 researchers have been involved and over 400 graduate and undergraduate students supported. During the past eight years the PD/A CRSP has worked (or is currently working) with 18 US universities in 16 states. This vital capacity-building has enhanced and strengthened host countries' abilities to further develop aquaculture and provide an additional and much needed protein source to the local and regional populations. However, USAID funds have been far too limited to develop long-term University centers of excellence in capture fisheries and aquaculture; plus the CRSP lacks a broader mandate in order to engage fully in the urgent issues of nearshore and inland fisheries, marine aquaculture, coastal area management, and the comprehensive, systems-based natural resource management approaches we recommend that would ensure a sustainable future for capture fisheries and aquaculture. The USAID needs to examine how the CRSP, the USAID Cooperative Agreements, and other current/past administrative initiatives in coastal management and aquaculture could be used as models to expand long-term engagement in critical regional issues that have place-based centers and can involve an expanded collaboration between USAID/Government/Universities that could build on America's strengths and competitive position.

Foreign nationals need specialized short and long-term training in the US. Trained human resources are essential to resource management, which require, inter alia: multi-disciplinary expertise in fishery resource assessment; bio-economic and socio-economic analysis; management techniques; fishing technology, marketing and quality control; resource monitoring; fishery surveillance; and fisheries legislation. The USAID Cooperative Agreements in aquaculture, fisheries and comprehensive coastal area management with American universities were very effective programs for capacity building worldwide. These Agreements created an impressive cadre of globally important leaders—and good will—in fisheries and aquaculture throughout the academic and governmental institutions of many nations. We urge USAID to enhance its commitments to the building of additional leadership capacities in developing nations by elevating overall human resource capabilities to better manage fisheries and aquaculture. Additional Cooperative Agreements for training on a variety of concepts and skills are needed in order to have a chance at sustaining and rehabilitating fisheries and aquaculture ecosystems in many nations, to strengthen institutions, and to improve individual performance. We recommend USAID to:

- Increase funding to and the participation of American scientists in The World Fish Center, and more generally, in the current and planned activities in fisheries and aquaculture of the Consultative Group in International Agriculture Research (CIGAR),

- Participate actively in the UN/FAO Associate Professional Officer program, so that young professionals can gain varied and broad global experiences in international settings,

- Increase the recruitment of fishery and aquaculture graduates into USAID missions and train them more extensively in pre-service at American universities,

- Fund or facilitate additional foreign student degree and certificate programs in fisheries and aquaculture and associated resource sciences at US institutions (both at universities and at US government organizations),

- Fund or facilitate additional targeted technical assistance missions (social science, economics, fisheries management, processing, labeling, GIS, HACCP, etc.),

We recommend that USAID lead a planning process that could result in establishment of formal collaborations with a suite of US government/University centers of excellence—possibly using an expanded and better funded CRSP mechanism—in order to develop additional applied science and extension/outreach capabilities in capture fisheries and aquaculture, and to better organize long-term, strategic and medium-term implementation plans and regular impact assessments of an expanded USAID portfolio in capture fisheries and aquaculture.

3. *USAID needs to bridge the "digital divide" to develop solutions to fisheries and aquaculture issues in developing countries.*

The Internet, supported via cable and satellite, can be an outreach pipeline, not only for spatial analyses, but also for moving more general information on fisheries and aquaculture to developing countries. There is a vast storehouse of fisheries and aquaculture information in the form of on-line technical reports and publications from US government and state agencies, NGOs, universities, professional organizations, and industry that could be "piped" abroad via the Internet. In many cases, simply raising awareness of the availability and location of the material would suffice as a useful intervention. Distance learning via the Internet, TV and radio is increasingly being used for training in developing countries. Even though, the US possesses the means to be effective in these media, training on fisheries and aquaculture using these media is not yet common.

Solutions to the problems of fisheries and aquaculture share a fundamental need of basic comparative information on causes and pathways. Nearly all of the issues are not isolated; rather they are shared by neighboring communities and countries, or topically right around the globe. Furthermore, many of them already have been experienced and treated in many areas of the world, prominently in the USA. A fundamental problem is that the applied science that has been employed and experience gained in surmounting the issues is not yet readily available to the developing world at acceptable costs. Therefore, an important advancement of USAID could be an initiative to help bridge the "digital divide" by increasing its emphasis on identifying, compiling and packaging solutions to fisheries and aquaculture issues of developing countries, and by broadening USAID involvement with many organizations specialized in technical, social and economic solutions in fisheries and aquaculture for which the USA has a comparative advantage **(Appendix 4)**—especially by taking advantage of the latitude within USAID for developing a broad variety of initiatives that include the US federal government and state agencies, commercial firms, NGO's, Land/Sea Grant universities, regional aquaculture centers, and international organizations. Several kinds of USAID initiatives are required to:

- Synthesize, package, and deliver applied research information by enhancing extension systems to move information to developing countries and to disseminate it in an effective manner;

- Assess the potential of distance learning to significantly improve technical and managerial competences in fisheries and aquaculture in developing countries;

- Facilitate information flow via choosing methods of information delivery that are appropriate for different audiences in different regions (increasing Internet access, radio, CDs, DVDs, videos, etc.);

- Sponsor collaborative in-country research between US professionals and applied fisheries and aquaculture professionals in developing nations on problems that are indigenous to the country or region.

We applaud the Pond Dynamics/Aquaculture CRSP in its development of the Amazon Aquaforum, an Internet-based information exchange aquaculture network in South America which supported development of a variety of technologically appropriate information delivery methods. The CRSP also maintains an invaluable, comprehensive, standardized database of information collected from throughout the world. The CRSP developed a web-based resource for small and medium-scale farmers in Latin America called the Web-based Information Delivery System for Tilapia (WIDeST), a decision-making tool that enables users to gain access to useful resources when deciding on appropriate, site specific methods and aquaculture practices.

4. *USAID should prioritize the improved management of coastal marine and inland fisheries by providing technical assistance to evolve innovative fisheries management schemes in developing countries including but not limited to: property rights, co-management, and the use of marine protected areas; plus assist in the development of more accurate and reliable fisheries and aquaculture data reporting systems.*

USAID needs to invest additional resources to assist in achieving the long-term goal of sustaining the world's invaluable marine and inland capture fisheries, which are disproportionately located in developing countries. Additional investments in capture fisheries could positively impact and better leverage USAID's current and planned investments in coastal area management and aquaculture. Additional assistance is needed to engage users and government institutions to bolster management and governance structures to address issues of overcapacity, access, marine tenure, critical habitats and nurseries, and a priority range of social issues such as gender relations. Investigations are needed into conservation engineering (innovative gears and management); roles of reserves, protected and conservation areas; plus investigations regarding how best to protect freshwater flows to estuaries (and rivers to lakes)—especially the timing, volume, quality and pulsing of freshwater flows to critical estuaries. In addition, the USAID could play a major role in analyzing and promoting effective fisheries management, government policies, reforms, market/trade policies, and reductions of subsidies.

In comparison to the long-standing emphasis on technical investments in fisheries for stock assessments, etc., comparably little attention has been paid to the users of fishery resources. This is despite the fact that the observed successes, failures, and constraints experienced in marine and inland capture fisheries management are social and economic in nature. Another problem is that fishery researchers often have a low status and income in a given national context, have limited facilities and resources, few opportunities for in-service training, and have limited access to outside scientific research information. We recommend that the USAID expand its investments in the community-based management of marine protected areas, property rights, and overall investments in social ecology and ecosystems-based management of fisheries.

Illegal, unreported and unregulated fishing is found in all capture fisheries, irrespective of the location, species targeted, fishing gears employed or level and intensity of exploitation. USAID should work with the reporting countries to improve fishery statistics, primarily to meet national needs with regard to food security and fisheries management. Unlike capture fisheries, the separate monitoring of aquaculture is relatively new in most countries, and often there are less well-established systems of data collection as compared to capture fisheries.

5. ***USAID needs to substantially increase its support to develop more comprehensive, sustainable, ecologically and socially compatible, environmentally-friendly and economically viable aquaculture systems in developing countries that have the long-term goals of poverty alleviation and food security.***

To meet global demands for fisheries products, aquaculture will continue to grow at a rapid pace over the next 10 years; then, its rate of growth will slow until the considerable environmental constraints it faces are solved. Aquaculture faces a number of important problems, including access to appropriate technologies, lack of comprehensive, inter-sectoral planning, a lack of financial resources for the poor, information on its environmental and social impacts and diseases. The priority areas for further applied research support include:

- land, water and feed/nutrient use in aquaculture in comparison with other animal protein production systems;

- sustainable intensification and non-consumptive water use in freshwater aquaculture production;

- participatory management approaches to the comprehensive development of aquaculture ecosystems as sustainable means of rural development;

- sustainable coastal aquaculture development, especially technologies that avoid user conflicts;

- social and economic research to add insights into the adoption of aquaculture by poor rural households;

- genetically advanced technologies for sustainable stock enhancement and ranching programs, plus the domestication, selective breeding, and genetic improvement of existing aquaculture species;

- technologies to solve disease problems and innovative management solutions to improve the health of aquatic animals;

- development of low cost, non-fish meal based feeds;

- training in the quality and safety of aquaculture products; and

- research in making emerging technologies cost-effective, including recirculating systems, and offshore aquaculture systems.

The appropriate role for the USAID in fisheries and aquaculture biotechnology is to support applied research and outreach activities that engage in well-known, conventional genetic improvement techniques, such as selective breeding, etc., as opposed to research support to advanced biotechnologies, such as transgenics. USAID support for The World Fish Center's program on the genetic improvement of farmed tilapias (GIFT)—and the development of international protocols for product dissemination—is an excellent example of the types of biotechnology investments the merit USAID's future consideration. However, it is also very important that USAID engage nations who have large and active programs in advanced fisheries/aquaculture biotechnology—such as China—in issues of policies, protocols, environmental, market and other social impacts of transgenics.

6. ***USAID should prioritize its assistance to capture fisheries and aquaculture activities that are more integrated, comprehensive, community-based, and use "systems approaches"—such as ecological and integrated farming/fishing systems research and extension approaches—in both rural and urban settings. The current agriculture emphasis of USAID is on plant commodity research, not on a comprehensive, agro/aqua-ecosystems research/extension approach. We urge the USAID to support long-term, applied research and development that makes expanded use of participatory ecological and social science tools to empower community control of fisheries and aquaculture systems; and to better integrate aquaculture and fisheries activities into the comprehensive management of natural and social resources of its missions, target nations and regions.***

The kinds of assistance provided by USAID should be based on a combination of: (1) assessed needs and capabilities in developing countries, and (2) the comparative advantages held by the USA in technical expertise, education, communications, business management and commercial products **(Appendix 4).** Assistance focused on US comparative advantages provides a way to get around duplication of effort among competing international organizations, while still fully supporting the Code of Conduct for Responsible Fisheries. The top priority for USAID should be the sustainable development of community-based, integrated farming and fishing systems with the long-term goals of poverty alleviation and food security.

Aquaculture and fisheries activities are frequently poorly planned and considered; funded separately from activities that greatly impact them; and are generally neglected by all levels of government. Fisheries activities should be planned as a continuum, and comprehensively as part of the planning for integrated natural resources management (water, wastes, agriculture, etc.), and the sustainable development of human communities. Fisheries and aquaculture information should be linked/coordinated with activities in other sectors (e.g., agriculture, forestry, food processing, distribution, etc.). Fisheries and aquaculture should be planned up-front—not as an afterthought—in all water resource development projects such as reservoir and irrigation projects. Coordination is both justified and essential because of shared issues with other sectors of sustaining biodiversity, maintaining water quality and quantity, the management and development in coastal areas and in river and lake basins, and addressing environmental degradation, mitigation and restoration, and the need to improve governance. USAID is encouraged to prioritize its support to applied research and development activities that articulate well with the natural and social resource and farming systems contexts of a nation/region, and (a) plan for the activities as one part of a comprehensive management strategy for the non-consumptive, multiple uses of water; and (b) use ecosystems-based management approaches that promote the more comprehensive, long-term stewardship of marine and freshwater environments.

We urge the USAID to support the expanded use of participatory tools to empower community controls over fisheries and aquaculture systems; to use innovative co-management methods to sustain local water and coastal resources, and the community-based management of water bodies for fisheries and aquaculture. Fisheries and aquaculture provide foods of very high nutritional value for households. When resource-poor fishers and farmers combine fisheries, agriculture, aquaculture and the conservation/rehabilitation of natural resources in innovative "ecosystems approaches"' they improve their food supplies, increase their incomes, and become better able to withstand environmental and economic fluctuations; thereby decreasing risks, increasing fishing and farm sustainability, and contributing greatly to rural social and economic development. We encourage the USAID to incorporate additional, applied social science and micro-economics research into innovative ecosystem-based methods that empower communities to better manage and control fisheries systems, and to develop more environmentally and socially compatible aquaculture systems (protected areas, property rights, innovative co-management approaches, etc.). Most of the modern aquatic resource crises have roots in social issues that are poorly known, such as the "shifting nature of modern survival" in developing nations. Millions of people do not only fish or farm, rather, they derive income from multiple activities and sources, and in some cases, conduct long distance seasonal migrations between inland farming systems and fisheries systems, and vice versa. USAID is encouraged to support the development of aquaculture systems that are well integrated into existing water resource systems, are virtually non-consumptive of water, and make multiple uses of water.

Aquaculture has the potential for small business development but additional technical assistance is needed by business professionals familiar with economics, labor dynamics, opportunity costs, issues of price and volume competition, and other commercial and competitive contexts of other sectors such as agriculture, etc. The recent activities of the Pond Dynamics/Aquaculture CRSP (PD/A CRSP) are notable in this regard. In 2002, the CRSP conducted regional meetings in Latin America, the Caribbean, Africa, and Asia, plus commissioned a report to explore the current status of aquaculture in Eastern Europe/Central Asia. Participants represented diverse areas of expertise; gender diversity was also a criterion of panel composition. During the meetings, participants were asked to identify and prioritize constraints to aquaculture development in the region of their expertise. Three central needs-directed program areas emerged after analyzing the results of the meetings. This movement of the PD/A CRSP to become more of a "system-oriented" network as opposed to a "commodity" collaborative is noteworthy and laudable; and if additional resources were available, these concepts could be developed further.

We cannot emphasize more strongly that poorly-funded, short-term projects with broad, "global" goals will not make lasting impacts on the conservation and sustainable development of fisheries and aquaculture systems in developing countries; and that these approaches do not serve the strategic interests of the United States. Research, education and extension assistance must target the long-term engagement of institutions, and deliver approaches, findings and insights towards these institutional systems and organizations that will continue the long-term engagement with farmers/fishers that can weather the invariable fluctuations in development assistance that will occur over time.

7. *USAID needs to develop comprehensive strategic and implementation plans and regular impact assessments of an expanded capture fisheries and aquaculture portfolio. USAID missions and regions worldwide should include capture fisheries and aquaculture into their strategic plans for the management of natural resources—or they will be incomplete—especially in regards to USAID plans for involvement in the issues of water allocation and quality, and plans for the comprehensive management of marine and inland coastal areas.*

USAID needs to sustain a strategic, long-term commitment to fisheries and aquaculture as parts of comprehensive natural, aquatic resource management. Short-term projects should be part of larger, longer-term strategic frameworks for directed action that have adequate accountability to measure strategic progress and impacts. USAID needs to conduct regular, transparent processes that result in the publication of strategic and implementation plans for fisheries and aquaculture over 5 to 10-year time frames. The movement from short term projects to longer term investments in centers of excellence, for example, will require the USAID to develop strategic planning and assessment processes that are much more comprehensive and "living". With more stable investments strategic plans have a shorter "shelf life" and require more frequent review and evaluation in order to make the necessary "mid-course changes". We recommend a process similar to that used by Standing Committees of the U.S. National Research Council where external expert advisors regularly measure progress on investment portfolios.

Within the fisheries sector, USAID should take advantage of shared needs for land and water resources and issues in common to identify sub-sector groupings for directed technical assistance and development activities. We identify two groups that require distinct interventions: (1) offshore (i.e., within the EEZs) and high seas fisheries share common issues of resource and fisheries management that include shared resources, over harvesting, and excess capacity, and (2) coastal and inland fisheries as well as aquaculture to a great extent, may interact both positively and negatively with one another, sometimes competing for space, resources and markets, but they also share many common issues that are external to the fisheries sector, most importantly the environment and poor governance.

VII. Appendicies

Appendix 1. Importance of Feeds for the Future of Aquaculture

Fish meal has been the protein source of choice in diets for farmed fish for several reasons. First, the protein content of fish meals is relatively high, generally 65-72%, depending upon the fish species used to produce the fish meal. Second, the amino acid profile of fish meal closely matches the dietary requirements of most carnivorous fish species. Third, protein and amino acid apparent digestibility is relatively high in good quality fish meal in most farmed fish species.[58] Finally, fish meal-based diets are highly palatable to most farmed fish. Of these properties of fish meal, plant protein sources are similar with respect to apparent protein and amino acid digestibility, and protein concentrates are similar to fish meal in protein content. However, amino acid profiles of plant protein sources do not match the dietary requirements of carnivorous fish species as well as do the amino acid profiles of marine proteins, and some plant protein sources lower feed intake, presumably by lowering feed palatability, when replacement levels are high. Thus, the role of plant proteins up to now has primarily been to replace a portion of the fish meal protein in diets for carnivorous fish species to lower the price of the feed, extend fish meal supplies when they are tight, or to reduce the total phosphorus level of the diet. Certain protein ingredients from the rendering industry, e.g., blood meal and feather meal, have been used in a similar fashion, and also to increase the total protein level of the diet.

The amount of protein supplied by fish meal in diet formulations for various species of fish differs significantly, depending on whether or not the species is carnivorous or omnivorous. Salmon and trout, for example, are fed diets that contain 38-44% crude protein during the grow-out stage, where most feed is used during a production cycle.[59] Catfish, in contrast, are fed diets containing 28-32% crude protein, most of which is supplied by soybean meal.[60] Members of the carp family are fed diets with protein contents varying from 0 to 35%, depending on species, where they are farmed and life-history stage.[61,62] Fry and fingerling carp are fed diets containing higher protein levels than are post-juvenile fish. Carp diets intended for use in high-input rearing systems contain 15-25% fish meal, and although this is a relatively low fish meal inclusion level, the tremendous increase in high-input carp culture has dramatically increased the amount of fish meal used by this production sector to about 17% of the total amount of fish meal used in all aquaculture diets in 2000.[15] Together, 2.1 million tons of fish meal was used in diets for fish and shrimp in 2000. The percentage of fish meal in the diet of various species groups ranged from 55% for marine flatfish (flounder, turbot, halibut) to 3% for catfish (channel catfish, African catfish). Carp averaged 5%, but this figure includes both high-input and low-input systems. Carp farming is converting to high-input systems, and this will increase the total use of fish meal in this production sector, despite an anticipated reduction in the percentage of fish meal used in diets.[15] Carp feed production is anticipated to increase from about 7 million tons in 2000 to 27 million tons by 2010. Soybean meal will likely supply the bulk of protein in carp diets of the future, but fish meal will continue to be used, especially in diets for fry and fingerling carp.

Barlow[15] predicted that aquaculture feed production would increase from 13.1 million tons in 2000 to 37.2 million tons in 2010. At today's fish meal use levels in diet formulations for various species groups, the amount of fish meal needed to produce 37.2 million tons of fish and shrimp feed would slightly exceed the amount of fish meal traded worldwide in non-El Nino years. However, Barlow[15] predicts that the percentage of fish meal in diet formulations will decrease and that total fish meal use by the aquaculture industry will be 2.8 million tons of fish meal in 2010. Total protein in these diet formulations will not change. The difference between 4.6 million tons and 2.8 million tons, e.g., ~1.7 million tons, will be supplied by other protein sources. Assuming that the fish meal used in fish feeds contains 70% crude protein, then ~1.2 million tons of protein from sources other than fish meal will be needed annually in fish feeds by 2010. If soybean meal (48% crude protein) were used to supply this protein, the increase in total use in all aquaculture feeds would be ~2.6 million tons. If soy protein concentrate were used, the total would be less, approximately 1.6 million tons because of its higher protein content. If other protein concentrates from grains or oilseeds, e.g., wheat gluten meal, corn gluten meal, canola protein concentrate, were used, the amounts would be similar.

Appendix 2. Eleven "Great Trends" Identified by the SPARE Panel

1. We live in a closely connected world in the midst of a communications revolution, where an acceleration of the pace of change is occurring.

2. We live on human-dominated marine and inland coasts; these coastal societies are removing invaluable ecosystems and habitats at unprecedented rates and delivering never-before seen levels of pollution to aquatic ecosystems. These major "drivers of change" are putting into question the future survival of the world's traditional, working coastal societies.

3. Urbanization and agriculture are causing increasing water shortages in many societies. Water withdrawals from freshwater and estuarine ecosystems are having large-scale impacts on aquatic ecosystems.

4. Because of the shift to the coast, the coherency of individual stakeholder groups is disappearing. Instead of a "fishing community" we have multiple users struggling for survival, with many groups shifting around between sectors and geographic regions. Large-scale seasonal migrations between inland and coastal ecosystems and cities now occur regularly. Our attention to and understanding of this "shifting nature of survival" is very poor.

5. We live in a transitional time in fisheries where economic failures and huge subsidies in fishing are occurring. However, this situation is changing rapidly. We expect the next big international battlefront will be fishing subsidies: which countries are handing them out; and what should be done about them.

6. Commercial fishing and global fishing fleets will continue to shrink. The silver lining is that we might end up with a much more efficient and financially sound fishing fleet in 20 years.

7. There is a dramatic globalization and consolidation of seafood trade and labor, with a major shift of seafood production to developing countries. The longer the world economy remains sluggish; the more consolidation we are likely to see.

8. Continual failures to manage capture fisheries rationally have led to a global aquaculture industry growing more rapidly than any other resource-based sector. Aquaculture will grow at an even quicker pace over the next 20 years, then slow due to environmental constraints.

9. Concerns over the safety and purity of the food we put in our mouths is fueling a new era of food safety. Expect more food safety regulations in the future. Expect environmental labeling and other market-based approaches to ensuring sustainable fisheries and aquaculture to become commonplace worldwide.

10. There has been a spectacular rise in the power and scientific capabilities of international NGOs. While NGOs have filed lawsuits and started boycotts, expect them to challenge the university and government science and management establishments more regularly. One reason for this is the terrible government neglect of applied fisheries and aquaculture science and management institutions in government and universities worldwide.

11. Lastly, in the midst of these breathtaking changes and extraordinary challenges, the "sustainability imperative" has arisen like a phoenix. But to date, governments and sustainability visionaries have given little attention to the dire needs of the living resources of the world's oceans and freshwaters.

Appendix 3. Lessons from Agroecology

There are many opportunities for aquaculture and fisheries to employ farming systems research and extension methods derived from agroecology to aquaculture farming and fishing systems in developing countries.[40] By a recent estimate, some 4.4 million farmers applying agroecological methods have achieved productive results, mostly in marginal environments. Farmers using agroecological models have achieved significant levels of production security while also achieving natural resource conservation. Farmers employ methods such as polycropping, crop-livestock integration, agroforestry, integrated soil management and integrated pest management and have been shown capable of producing substantial and secure yield increases.[63] Conversion to agroecological methods requires more labor, significantly greater contributions of farmers' knowledge, and greater "adaptive abilities". After the ecological infrastructure is established, however, agroecosystems are able to sustain their own plant protection, soil fertility, and farm productivity.

Agroecology consists of a universal set of principles, which translate into site-specific technological forms according to local needs and socio-economic circumstances. Farmers' knowledge and experimentation are essential resources. New strategies focus on the facilitation of farmer learning to become experts in natural resource management, and the involvement directly in the formulation of the research agenda, with active participation in the process of technological innovation and outreach/dissemination. In addition, researchers focus their attention on translation of general ecological principles of natural resource management into practical advice directly relevant to smallholder farmers.

Even though there is now greater interest in diverse, low input systems, agroecological systems are not regarded by many agricultural scientists as capable of meeting the production needs of the future. As a result, research on agroecology has been largely ignored by mainstream agricultural research, which has continued to pursue conventional approaches toward yield maximization of specific crops with large external inputs, and biotechnology.

Appendix 4. Comparative Advantages of the USA in Fisheries and Aquaculture

The USA possesses many comparative advantages over other nations in a number of disciplines, techniques and technologies. These advantages should be applied in a systematic way to resolve issues in fisheries and aquaculture among developing countries. Here we use comparative advantages related to geographical information systems (GIS), remote sensing, mapping and GPS to illustrate the issues, spatial solutions, comparative advantages and the strategies that should be considered for implementation. The strategies are general, and many comparative advantages in other fields could be listed.

Aquaculture has grown at a rapid pace, especially in recent years. Nevertheless, unplanned growth, or growth that was poorly planned, has resulted in a number of social, economic, environmental and administrative problems. Likewise, coastal and inland food fisheries continue to be threatened by degradation of the environment and overfishing. The confluence of these problems makes the sustainability of aquaculture and inland fisheries the central issue. All of the main issues in aquaculture and inland fisheries have spatial elements to some degree, and several of the issues quite explicitly call for spatial solutions that can be most effectively addressed by the deployment of GIS, remote sensing and mapping individually, or in concert.[64] For example, fisheries[65,66] and aquaculture[67,68] problems that have been addressed by GIS, remote sensing and mapping include: (1) Zoning for fish reserves, and for aquaculture development; (2) Identification of essential fish habitat; (3) Aquaculture information systems for planning and management of aquaculture among government agencies; (4) Assessing the potential for aquaculture development (suitability for systems and productivity of organisms); (5) Integrating fisheries and aquaculture into coastal area management, and river and lake basin management; (6) Assessing the status of fishery resources and of aquatic habitats; (7) Estimating environmental impacts on fisheries and aquaculture, and planning for mitigation; (8) Estimating the effects of fisheries and aquaculture on the environment;

and (9) Aquaculture and fisheries early warning (e.g., harmful algal blooms, lethal temperatures). A salient problem is that, with few exceptions, developing countries that contribute most importantly to global aquaculture and inland fisheries production appear not to be deploying GIS, remote sensing and mapping tools to improve the sustainability of these sectors.

The USA has a marked advantage in spatial analyses. In the realm of aquaculture, the USA accounted for 36% of all global applications of GIS from 1985 to 2002. The situation is even more remarkable with respect to inland fisheries: the USA accounted for 71% of the world total. Experience in these applications comes from a variety of sources: US government, state and local agencies, universities, and NGOs.

The USA is the world leader in the development and marketing of GIS software. In a related field, the US dominates in inexpensive global positioning system (GPS) units that have become indispensable for incorporating ground and aquatic field data into maps and GIS. More generally, the USA is the preeminent provider of inexpensive computers, peripherals and software, including Internet servers. The US government operates a range of satellite-borne sensors, some of which are especially designed to collect data from aquatic environments. The coverage is frequent and world wide. Historical data are archived making change analyses possible. These data are the potential backbone of much of the spatial analyses needed to address aquaculture and fisheries problems among developing countries.

The goal is to improve the sustainability of aquaculture and inland fisheries through practical, needs-driven training on applications of GIS, remote sensing and mapping. The following strategies are advocated:

- Place emphasis on achieving self-reliance in spatial analyses for fisheries and aquaculture in a measured, step-wise fashion with solutions appropriate to capabilities and sustainability, and frequent evaluation of results.

- Provide a range of services according to assessed needs and capabilities to sustain the initiatives provided via USAID. For example, because the statistical data are so incomplete, all fisheries and aquaculture organizations can benefit from mapping, but few countries in Africa could support a GIS aimed at fisheries and aquaculture alone.

- Concentrate on practical training in-country, and on fellowships that provide a wide range of theoretical and practical training in the USA.

- Distance learning via the Internet, TV and radio is increasingly being used for training in developing countries.[69] Even though the US appears to possess the means to be effective in these media, training on fisheries and aquaculture using these media is not yet common. This opportunity should be evaluated.

- Work with many organizations according to their comparative advantages: national and sub-national fisheries and aquaculture government entities, commercial firms, trade organizations, universities and professional organizations.

- In developing nations, work outside of fishery and aquaculture sectors with entities that have broader or overlapping responsibilities with the goal to integrate aquaculture and fisheries into broader GIS-based planning initiatives and to mobilize to issues of common concerns for the environment.

- A "Fisheries and Aquaculture International Training Coordination Unit" could be established in USAID to identify the training needs and opportunities, to contract with the providers and to evaluate the results of the training.

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Figure 1. World fishery production is approximately 142 million tons. Asia dominates all aspects of world fisheries production.

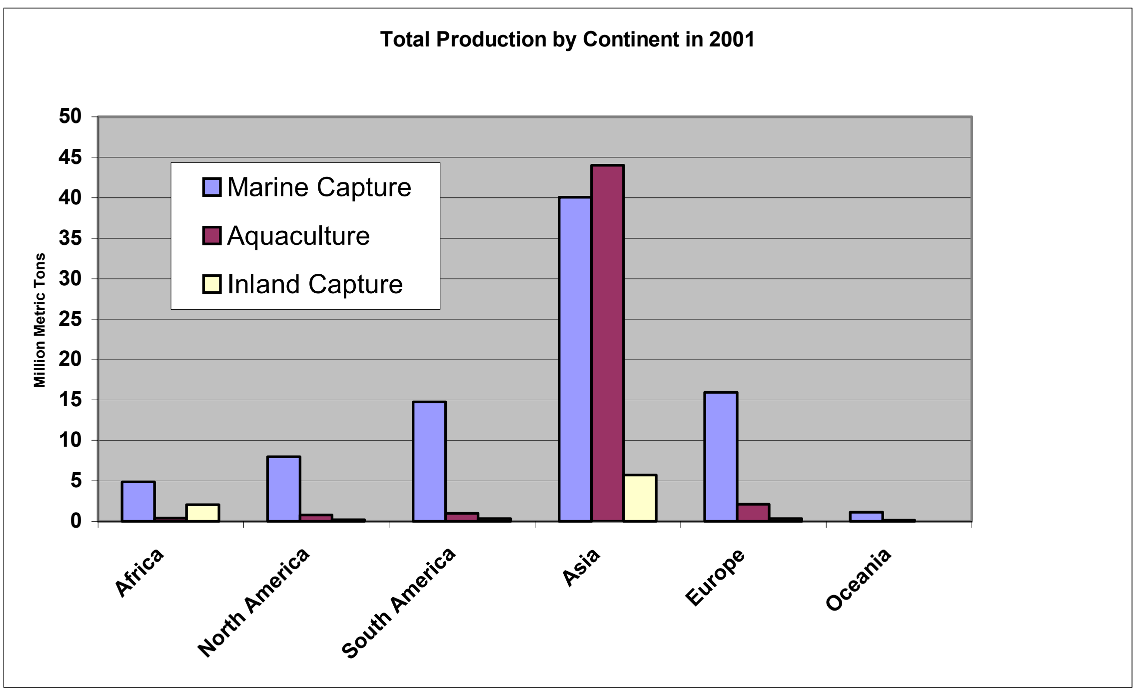

Figure 2. Worldwide trends in marine capture fisheries.

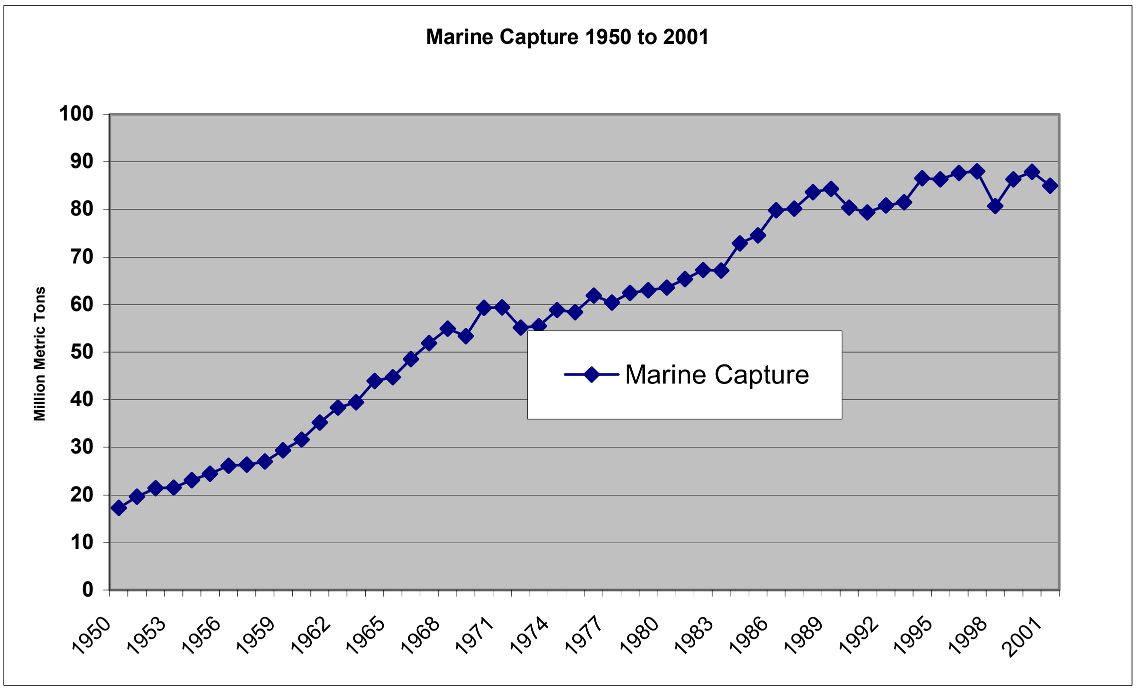

Figure 3. Worldwide trends in inland capture fisheries.

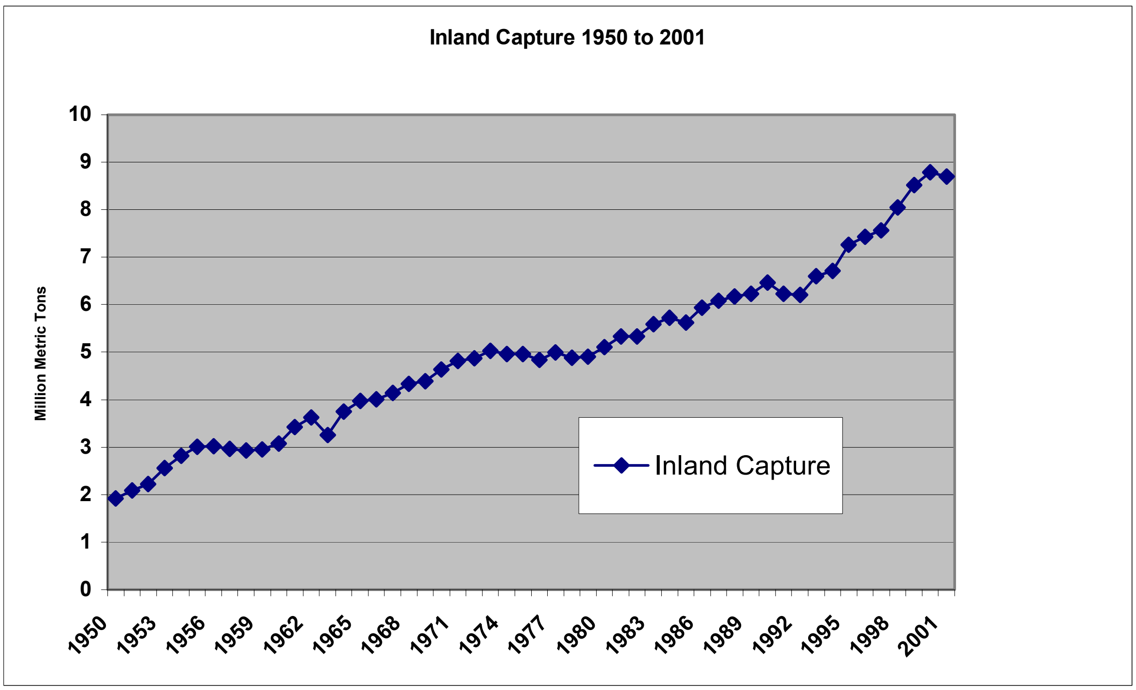

Figure 4. Leading countries in inland capture fisheries production. Two-thirds come from developing countries, with one-quarter from China.

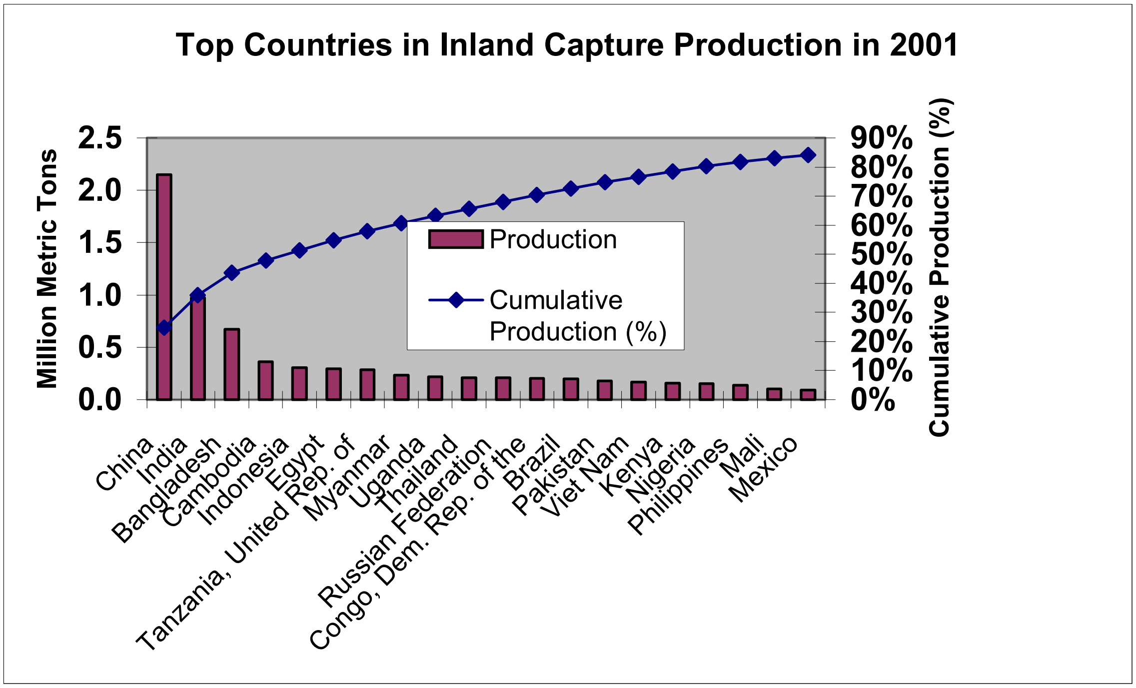

Figure 5. In 2001, 48.4 million tons of aquatic products (including plants) valued at US$ 61.5 billion were produced, with half of the production being finfish.

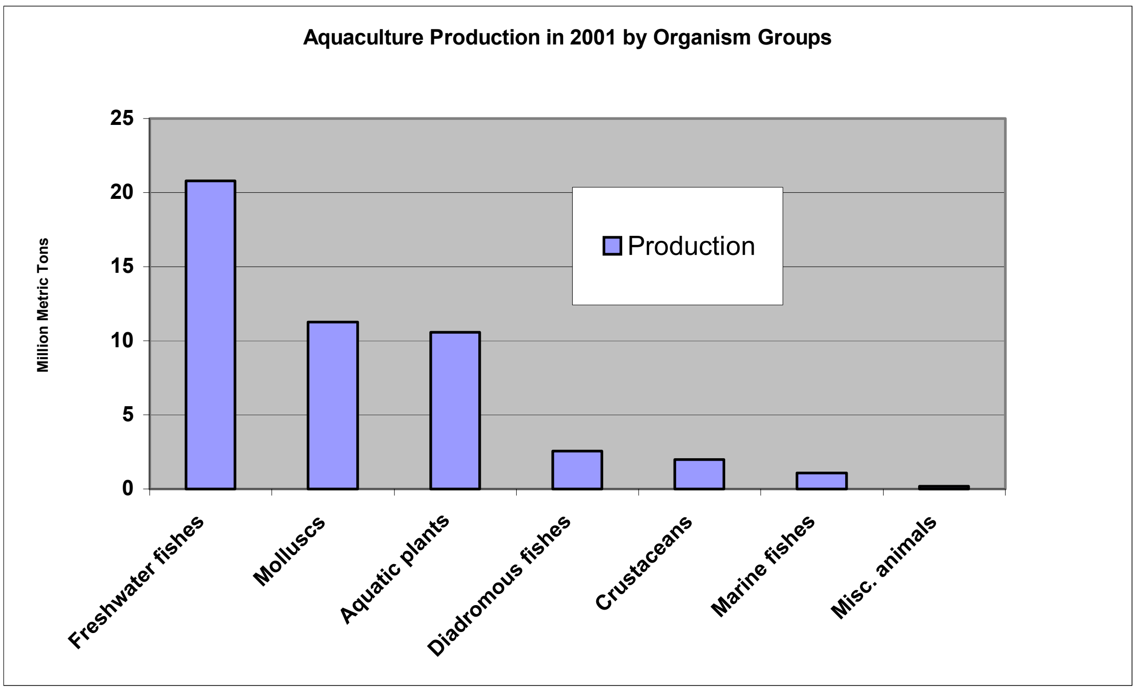

Figure 6. World aquaculture production by environment. About one-half of global aquaculture production is from freshwater and the other half from marine and estuarine ecosystems.