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POLICY BRIEF

The threat to fisheries and aquaculture from climate change

Key messages

- ***Significance of fisheries and aquaculture.*** *Fish provide essential nutrition and income to an ever-growing number of people around the world, often where other food and employment resources are limited. Many fishers and aquaculturists are poor and ill-prepared to adapt to change, making them vulnerable to impacts on fish resources.*
- ***Nature of the climate change threat.*** *Fisheries and aquaculture are threatened by changes in temperature and, in freshwater ecosystems, precipitation. Storms may become more frequent and extreme, imperilling stocks, infrastructure and livelihoods.*
- ***The need to adapt to climate change.*** *Greater climate variability and uncertainty complicate the task of identifying impact pathways and areas of vulnerability, requiring research to devise and promote coping strategies and improve the adaptability of fishers and aquaculturists.*
- ***Strategies for coping with climate change.*** *Fish can provide opportunities to adapt to climate change by, for example, integrating aquaculture and agriculture, which can help farmers cope with drought while boosting profits and household nutrition. Fisheries management must move from seeking to maximize yield to increasing adaptive capacity.*

The significance of fisheries and aquaculture

Population growth is accompanied by increasing demand for food fish, with direct human consumption of fish reaching an estimated 103 million tons in 2003. Fish is the main source of animal protein for a billion people worldwide (Figure 1). As well as providing a valuable protein complement to the starchy diet common among the global poor, fish is an important source of essential vitamins and fatty acids. Many coastal and island communities, where poverty is widespread and livelihood alternatives limited, depend heavily on fish resources. Small-scale inland fisheries are especially important to food security, and much of the fish caught is consumed locally.

Some 200 million people and their dependants worldwide, most of them in developing countries, live by fishing and aquaculture. Fish provides an important source of cash income for many poor households and is a widely traded food commodity that, in addition to stimulating local market economies, can be an important source of foreign exchange. Fishing is often integral to mixed livelihood

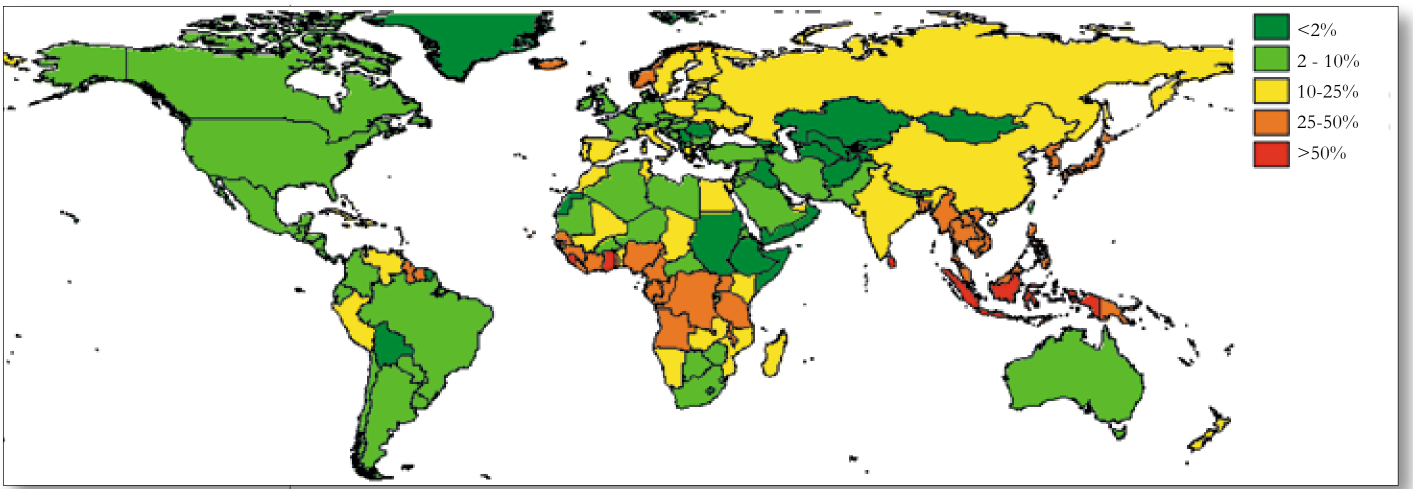


Figure 1.
National averages of fish protein as a percentage of total animal protein consumed (Handisyde et al. 2006).

strategies, in which people take advantage of seasonal stock availability or resort to fishing when other forms of food production and income generation fall short. Fishing often accompanies extreme poverty and may serve as a vital safety net for people with limited livelihood alternatives and extreme vulnerability to changes in their environment.

Globally, aquaculture has expanded at an average annual rate of 8.9% since 1970, making it the fastest growing animal food source. Today, aquaculture provides around half of the fish for human consumption, and this share will need to grow further because limited — and in many cases declining — capture fisheries will be unable to meet rising demand. Integrating aquaculture with agriculture by, for example, raising fish in rice fields or using agricultural waste to fertilize ponds, can provide significant nutritional and the economic benefits from available land and resources.

Climate change impacts on fisheries and aquaculture

Climate changes may affect fisheries and aquaculture directly by influencing fish stocks and hence production quantities and efficiency, or indirectly by influencing fish prices or the cost of goods and services required by fishers and fish farmers (Table 1).

Changing sea temperatures

Coral reefs provide a permanent habitat for many important fish species and are vital to the juvenile stages or food supply of many others. As well as providing direct benefits to fisheries, coral reefs perform a range of valuable services such as attracting tourists and protecting shore-

Figure 2.
Coral bleaching severity (ReefBase, www.reefbase.org).

● = No bleaching
● = Severity unknown
● = Low bleaching
● = Medium bleaching
● = High bleaching

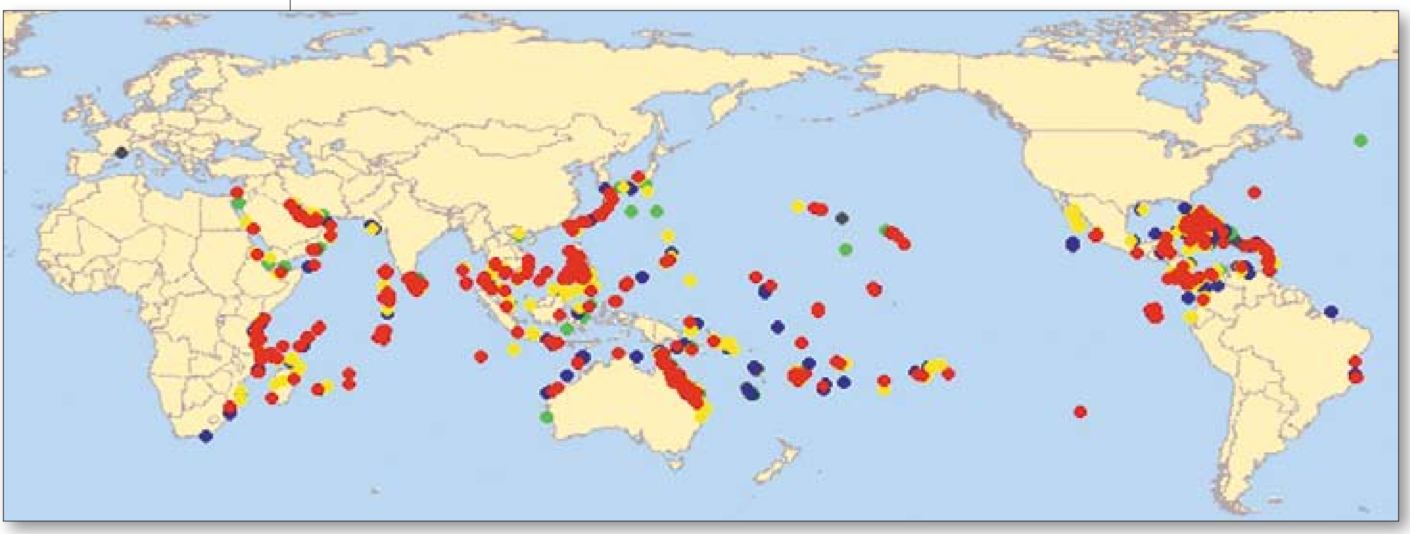


Table 1. Ways in which climate change may directly affect production from aquaculture and fisheries

Drivers	Effects	Implications for aquaculture and fisheries
Higher inland water temperatures	Increased stratification and reduced mixing of water in lakes, reducing primary productivity and ultimately food supplies for fish species.	Reductions in fish stocks.
	Raised metabolic rates increase feeding rates and growth if water quality, dissolved oxygen levels, and food supply are adequate, otherwise possibly reducing feeding and growth. Potential for enhanced primary productivity.	Possibly enhanced fish stocks for capture fisheries or else reduced growth where the food supply does not increase sufficiently in line with temperature. Possible benefits for aquaculture, especially intensive and semi-intensive pond systems.
	Shift in the location and size of the potential range for a given species.	Aquaculture opportunities both lost and gained. Potential loss of species and alteration of species composition for capture fisheries.
	Reduced water quality, especially in terms of dissolved oxygen. Changes in the range and abundance of pathogens, predators and competitors. Invasive species introduced.	Altered stocks and species composition in capture fisheries. For aquaculture, altered culture species and possibly worsened losses to disease (and so higher operating costs) and possibly higher capital costs for aeration equipment or deeper ponds.
	Changes in timing and success of migrations, spawning and peak abundance.	Potential loss of species or shift in composition for capture fisheries. Impacts on seed availability for aquaculture.
Changes in sea surface temperature	More frequent harmful algal blooms. Less dissolved oxygen. Increased incidence of disease and parasites. Altered local ecosystems with changes in competitors, predators and invasive species. Changes in plankton composition.	For aquaculture, changes in infrastructure and operating costs from worsened infestations of fouling organisms, pests, nuisance species and/or predators. For capture fisheries, impacts on the abundance and species composition of fish stocks.
	Longer growing seasons. Lower natural mortality in winter. Enhanced metabolic and growth rates.	Potential for increased production and profit, especially for aquaculture.
	Enhanced primary productivity.	Potential benefits for aquaculture and fisheries but perhaps offset by changed species composition.
	Changes in timing and success of migrations, spawning and peak abundance, as well as in sex ratios.	Potential loss of species or shift in composition in capture fisheries. Impacts on seed availability for aquaculture.
	Change in the location and size of suitable range for particular species.	Aquaculture opportunities both lost and gained. Potential species loss and altered species composition for capture fisheries.
	Damage to coral reefs that serve as breeding habitats and may help protect the shore from wave action (the exposure to which may rise along with sea levels).	Reduced recruitment of fishery species. Worsened wave damage to infrastructure or flooding from storm surges.
Changes in precipitation quantity, location and timing that alter water availability (changes in evaporation rates may also be significant).	Changes in fish migration and recruitment patterns as well as in recruitment success.	Altered abundance and composition of wild stock. Impacts on seed availability for aquaculture
	Changes in lake and river levels and the overall extent and movement patterns of surface water.	Altered distribution, composition and abundance of fish stocks. Fishers forced to migrate more and expend more effort.
	Lower water availability for aquaculture. Lower water quality causing more disease. Increased competition with other water users. Altered and reduced freshwater supplies with greater risk of drought.	Higher costs of maintaining pond water levels and from stock loss. Reduced production capacity. Conflict with other water users. Change of culture species.

Drivers	Effects	Implications for aquaculture and fisheries
Sea level rise	Loss of land.	Reduced area available for aquaculture. Loss of freshwater fisheries.
	Changes to estuary systems.	Shifts in species abundance, distribution and composition of fish stocks and aquaculture seed.
	Salt water infusion into groundwater.	Damage to freshwater capture fisheries. Reduced freshwater availability for aquaculture and a shift to brackish water species.
	Loss of coastal ecosystems such as mangrove forests.	Reduced recruitment and stocks for capture fisheries and seed for aquaculture. Worsened exposure to waves and storm surges and risk that inland aquaculture and fisheries become inundated.
Increase in frequency and/or intensity of storms	Large waves and storm surges. Inland flooding from intense precipitation. Salinity changes. Introduction of disease or predators into aquaculture facilities during flooding episodes.	Loss of aquaculture stock and damage to or loss of aquaculture facilities and fishing gear. Impacts on wild fish recruitment and stocks. Higher direct risk to fishers; capital costs needed to design cage moorings, pond walls, jetties, etc. that can withstand storms; and insurance costs.
Drought	Lower water quality and availability for aquaculture. Salinity changes.	Loss of wild and cultured stock. Increased production costs. Loss of opportunity as production is limited.
	Changes in lake water levels and river flows.	Reduced wild fish stocks, intensified competition for fishing areas and more migration by fisherfolk.
El Niño-Southern Oscillation	Changed location and timing of ocean currents and upwelling alters nutrient supply in surface waters and, consequently, primary productivity.	Changes in the distribution and productivity of open sea fisheries.
	Changed ocean temperature and bleached coral	Reduced productivity of reef fisheries.
	Altered rainfall patterns bring flood and drought.	See impacts for precipitation trends, drought and flooding above.

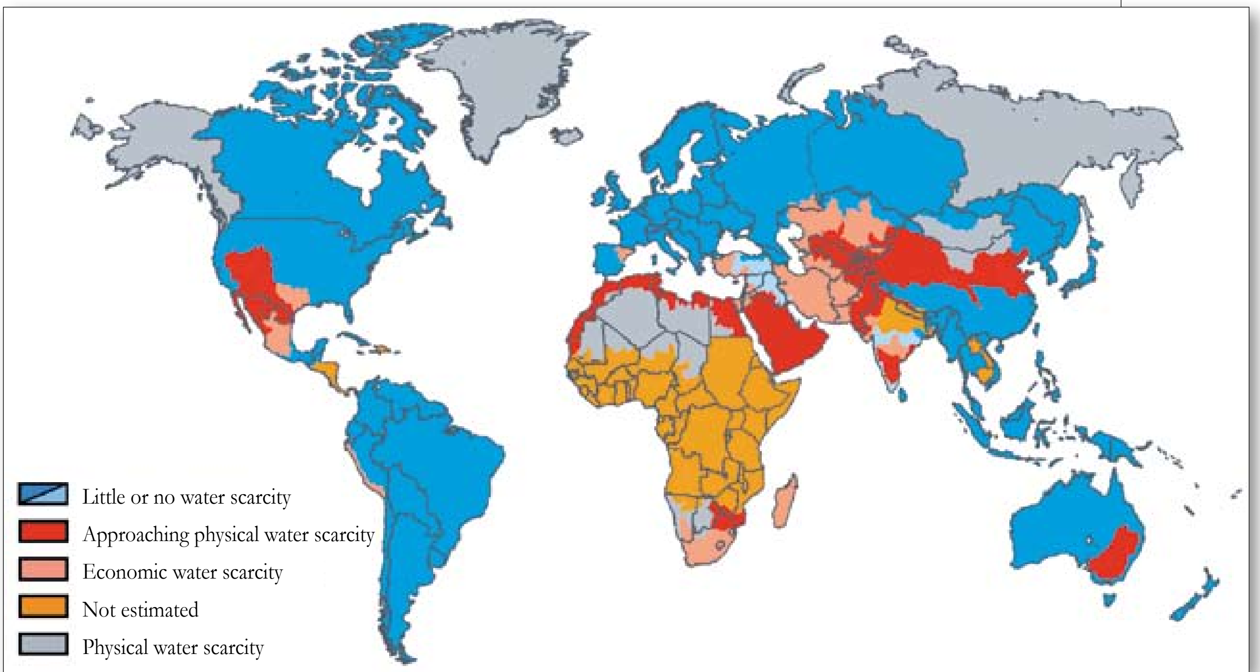
lines. The United Nations Environment Program (UNEP) estimates the annual value of coral reefs at $100,000-$600,000 per square kilometer. Tens of millions of people in over 100 countries depend at least partly on coral reef ecosystems for livelihoods or protein. People living in the coastal zone are often poor and landless, with limited access to services, and hence vulnerable to impacts on natural resources. Higher sea temperature is a major cause of coral bleaching and damage to reef ecosystems around the globe (Figure 2). The bleaching event of 1998, driven by El Niño, killed an estimated 16% of the world's coral. Studies suggest that 60% of coral reefs could be lost by 2030 and that increased acidification of oceans from higher levels of atmospheric carbon dioxide may be a contributing factor.

Changing sea temperature and current flows will likely bring increases, decreases and shifts in the distribution of marine fish stocks, with some areas benefiting while others lose. Research in this area typically focuses on higher-value commercial species. While investigating potential impacts on species important to poorer fishers is worthwhile, predictions will always be uncertain. This argues for a strong research focus on helping fishers become more able to cope with external shocks. Fishers need to reduce their reliance on narrow resources by learning to exploit a broader range of species and pursue alternative sources of income and fish production such as marine and brackish water aquaculture.

Rising sea level

Mean sea level is predicted to rise by 10-90 centimeters during this century, with most predictions in the range of 30-50 centimeters. This will likely damage or destroy many coastal ecosystems such as mangroves and salt marshes, which are essential to maintaining many wild fish stocks, as well as supplying seed to aquaculture. Mangroves and other coastal vegetation defend the shore from storm surges that can damage fish ponds and other coastal infrastructure and may become more frequent and intense under climate change. UNEP estimates the annual worth of mangroves at $200,000-$900,000 per square kilometer. A number of studies have identified possible adaptation strategies for mangrove systems that include raising awareness of the importance of these areas among local communities and leaders, identifying critical areas, minimizing stress unrelated to climate, maintaining ecosystem connectivity, coastal planning that facilitates retreat inland, developing alternative livelihoods, and restoring coastal ecosystems. Research to develop these strategies and the means to implement them is desperately needed.

Higher sea levels may make groundwater more saline, harming freshwater fisheries, aquaculture and agriculture and limiting industrial and domestic water uses. Increased inland groundwater salinity has been observed in Bangladesh in recent decades. Along with the negative consequences, however, come benefits in the form of increased areas suit-



Red: Physical Water Scarcity. More than 75% of the river flows are allocated to agriculture, industries or domestic purposes (accounting for recycling of return flows). This definition of scarcity—relating water availability to water demand—implies that dry areas are not necessarily water-scarce. For example, Mauritania is dry but not physically water-scarce because demand is low.
Light Red: More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.
Orange: Economic Water Scarcity. Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists. These areas could benefit by development of additional blue and green water, but human and financial capacity are limiting.
Blue: Abundant water resources relative to use: less than 25% of water from rivers is withdrawn for human purposes.

Figure 3. Global water scarcity (International Water Management Institute).

able for brackish water culture of such high-value species as shrimp and mud crab. This situation demonstrates the importance of maintaining people's capacity to recognize and take advantage of opportunities — and how aquaculture can play an important role in diversifying livelihoods.

Inland temperature changes

Higher inland water temperatures may reduce the availability of wild fish stocks by harming water quality, worsening dry season mortality, bringing new predators and pathogens, and changing the abundance of food available to fishery species. In Lake Tanganyika, which supplies 25-40% of animal protein for the countries that surround it, warmer temperatures reduced the mixing of surface and deep water layers in the last century, limiting the nutrients available to plankton and thereby cutting, by an estimated 30%, the yield in fish that feed on them. Identifying and promoting aquaculture species and techniques suitable to changing environments and resources will enable aquaculturists to adapt to change and may reveal new uses for land that has become unsuitable for livelihoods strategies that existed heretofore. Also noteworthy is that, in cooler zones in particular, aquaculture may benefit as rising temperatures bring faster growth rates and longer growing seasons.

Changes in precipitation and water availability

Changes in precipitation averages and potential increases in seasonal and annual variability and extremes are likely to be the most significant drivers of change in inland aquaculture and fisheries. Bangladesh, one of the world's least developed nations, relies on fisheries for around 80% of national animal protein intake. In the theoretical scenario of 2-6°C warming, precipitation is forecast to decline in Bangladesh during the dry season and increase during the wet season, expanding flood-prone areas by 23-39%. While a relationship exists between greater flooding extent and higher production in capture fisheries, potential benefits may be offset by a range of factors including reduced success of pelagic river spawners arising from higher river flows, reduced fish survival in lower dry season flows, and loss of habitat to new hydraulic engineering projects and other human responses. Damage to other livelihood and food production resources may also occur.

In many African lakes, water level determines stock fluctuations more than any other factor. This is especially true of lakes that periodically go completely dry, such as Mweru Wa Ntipa, Chilwa/Chiuta and Liambezi. In Lake Mweru and Lake Turkana, for example, catch rates decline when the lake level is low. Understanding how fisherfolk have adapted to variability through, for example, mixed livelihood strategies and the absence of barriers to entering fisheries, and how fisheries interact with other economic sectors may usefully guide responses to future climate variation and trends. Flexible management is the key to ensuring benefits flow from an unstable and uncertain resource.

Reduced annual rainfall, dry season rainfall, and growing season length are likely to have implications for aquaculture and create greater potential for conflict with other agricultural, industrial and domestic users in water-scarce areas (Figure 3). These impacts are likely to be felt most strongly by the poorest aquaculturists, whose typically smaller ponds go dry more quickly and who may suffer from shortened growing seasons, reduced harvests and a narrower choice of species for culture. That said, aquaculture may also provide solutions in areas of worsening water scarcity. Schemes that integrate pond aquaculture with traditional crops in Malawi have successfully reduced farmers' vulnerability to drought, provided a source of high-quality protein to supplement crops, and boosted overall production and profit. In terms of water use efficiency, systems that reuse water from aquaculture compare very favorably with terrestrial crop and livestock production.

Extreme events and worsening risk

Extreme events such as cyclones and their associated storm surges and inland flooding can wreak sudden and severe havoc on fisheries, and particularly on aquaculture, through damage or loss of stock, facilities and infrastructure. Institutional responses such as constructing artificial flood defenses and maintaining natural ones can provide protection that is significant but incomplete. Poor communities in exposed areas are unlikely to be able to build substantial defenses, so the most realistic and economic strategy will be to roll with the punches. In Bangladesh and other countries where floods are common, short culture periods and minimal capital investment in aquaculture help reduce stock loss and its cost. Building greater adaptive capacity will entail considering means, such as mixed livelihood strategies and access to credit, by which aquaculturists can cope financially with sudden losses of investment and income. Other considerations for coping strategies in high-risk areas include monitoring and assessing risk and promoting aquaculture species, fish strains, and techniques that maximize production and profit during successful cycles.

Wider implications of the impacts of climate variation on fisheries

Many artisanal fishers are extremely poor and, even when they earn more than other rural people, they are often socially and politically marginalized and afforded only limited access to healthcare, education and other public services. With little capacity to adapt, small-scale and migrant fishers are highly vulnerable to losses of natural capital from climate impacts and altered institutional mechanisms such as access agreements. Heightened migration to cope with and exploit climate-driven fluctuations in production may worsen a range of cultural, social, fisheries management and health problems. HIV/AIDS, which is prevalent in many fishing communities and will even become more so as climate change forces increased migration and social dislocation. As declining catches worsen poverty and food shortages, desperate people become less risk averse. Transactional sex, in which women fish traders around Lake Victoria, for example, trade sex for fish will become an increasingly important vector for the transmission of HIV/AIDS.

The need for further research, adaptive capacity and coping strategies

As the recent Stern Review on the Economics of Climate Change states, "For fisheries, information on the likely impacts of climate change is very limited." Efforts to increase understanding of how

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and why climate change may affect aquaculture and fisheries should emphasize developing strategies by which fisheries, and perhaps more significantly aquaculture, can play a part in our wider adaptation to the challenges of climate change. However, the inherent unpredictability of climate change and the links that entwine fishery and aquaculture livelihoods with other livelihood strategies and economic sectors make unraveling the exact mechanisms of climate impacts hugely complex. This argues for placing a very strong focus on building general adaptive capacity that can help the world's poor fishing and aquaculture communities cope with new challenges, both foreseen and not.

Further reading

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Intergovernmental Panel on Climate Change. 2001. Third assessment report. Available online at www.ipcc.ch (The fourth assessment report is due in the first half of 2007).

The WorldFish Center is an autonomous and nonprofit international research organization that works to reduce hunger and poverty by improving fisheries and aquaculture.

Now based in Penang, Malaysia, WorldFish was originally established in the Philippines in 1977 as the International Center for Living Aquatic Resources Management (ICLARM). In 1992 ICLARM became one of 15 research centers supported by the Consultative Group on International Agricultural Research (CGIAR). The CGIAR alliance mobilizes agricultural science to tackle poverty, foster human well-being, promote agricultural growth and protect the environment.

Major partners of WorldFish and the other CGIAR Centers include national agricultural research systems, international and regional agencies, conservation groups, non-governmental organizations (NGOs) and companies in the private sector. WorldFish activities are concentrated mainly in Asia, Africa and the South Pacific.

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