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The Impact of Water Security on Freshwater Fisheries Management: A Multinational Perspective

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Abstract.—Freshwater resources are rapidly decreasing in quantity and quality, thereby becoming stressed and, in many cases, becoming scarce for human and ecosystem use. Individuals and nations will need to modify their allocation of freshwater among users to preserve and conserve this resource, assuring that sufficient water is available to meet human and ecological needs. Freshwater needs of ecological systems are generally not considered when making water allocation decisions, unless mandated by local, national, or international laws. It is, however, undeniable that the health and productivity of a fish population is inextricably linked to the integrity of its freshwater ecosystem. This important link between freshwater and sustainable fishery makes it imperative for fisheries managers to understand and incorporate the use of freshwater resources by all sectors of society within their management plan. To accomplish this goal, however, two main factors need to be addressed, the first being society's valuation of fish populations, such as whether there is an imperative to maintain instream flows of sufficient freshwater for healthy fish populations, and the second being the need to eliminate the existing separation between water and fishery managers with the objective of integrating them into a common management system. In this paper, we evaluate management concerns regarding water use and its relative scarcity and how this impacts fisheries sustainability and productivity. We examine how a society's perception of the importance of maintaining sufficient instream flows to preserve fish populations is related to its reliance on its water resources and how this perception affects the approaches taken by that society to assure water security for locally embedded ecosystems and their fisheries.

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Introduction

Freshwater resources are rapidly decreasing in quantity and quality, thereby becoming stressed and. in many cases. becoming scarce for human and ecosystem use (Cosgrove and Rijsberman 2000). The scarcity of water is expected to worsen globally over the next 20 years as demand for the world's freshwater resources increases to meet the needs of the growing human population (Serageldin 1999). As these trends continue, individuals and nations will need to modify their allocation of freshwater among users to preserve and conserve this resource and to assure that sufficient water is available to meet human and ecological needs, referred to as water security for humans and ecosystems.

In 1990, the total amount of freshwater consumed was estimated at 4130 km^3 per year (total volume freshwater on earth is estimated at 35,029 $km^3 \times 10^3$), with 57% being irretrievably lost from the hydrologic cycle (Young et al. 1994). The amount of freshwater withdrawn is generally allocated to three main sectors, agriculture (70%), industry (20%), and domestic users (10%), with percentages varying by region and reflecting local communities' priorities (Postel 1997; Serageldin 1999; Cosgrove and Rijsberman 2000). Freshwater needs of ecological systems are generally not considered when making water allocation decisions, unless mandated by local, national, or international laws.

It is undeniable that the health and productivity of a fish population is inextricably linked to the integrity of its freshwater ecosystem. This important link between freshwater and sustainable fishery makes it imperative for fisheries managers to understand and incorporate the use of freshwater resources by all sectors of society within their management plan. To accomplish this goal, however, a few main factors need to be addressed: society's valuation of fish populations, whether there is an imperative to maintain instream flows of sufficient freshwater for healthy fish populations, and integration of water and fishery managers into a common management system. In this paper, we evaluate the management concerns regarding water use and its relative scarcity and how this impacts fisheries sustainability and productivity. Additionally, we examine how a society's perception of the importance of maintaining sufficient instream flows to preserve fish populations is related to its reliance on its water resources and how this perception affects the approaches taken by that society to assure water security for locally embedded ecosystems and their fisheries. The United States, China, and Malawi provide some insights on the spectrum of how societies value these resources.

Impacts of Water Stress and Scarcity

The impacts of water scarcity on the health of human populations and freshwater ecosystems are already being felt in many regions of the world (Postel 1996, 1997; Seckler et al. 1999). A common national response to increasing water scarcity has been to dam rivers to create reservoirs that allow water storage for future use. Additionally, groundwater sources are also used by nations to supplement inadequate surface water supplies. In most cases, these methods of storing freshwater and accessing additional sources to meet society's needs in the short-term aggravate the problem of water scarcity in the long-term by degrading water quality or reducing water quantity for other sources.

Dams, of which there are an estimated 45,000 exceeding 15 m in height worldwide (WCD 2001), significantly affect water quality and quantity by changing flow rate, water temperature, and sediment loading and by releas-

ing anoxic water in rivers. Groundwater withdrawal that exceeds the replenishment rate causes groundwater tables to recede deeper from the surface (Kuylenstierna et al. 1997). This recession eliminates the input of coldwater springs into streams and rivers, modifying the temperature regime, discharge, and biotic integrity of the river. At times, the withdrawal of water has been severe enough to result in the drying up of rivers and lakes (Seckler et al. 1999; Gleick et al. 2002).

Water stress and scarcity have been associated with the loss of many aquatic species (Gleick et al. 2002). The Aral Sea, with 94% of its river inflow being diverted, typifies the destructive impact of excessive water withdrawal on an ecosystem (Abramovitz 1996). The diversion of the Amu Darya and Syr Darya rivers, both water sources for the Aral Sea, led to a substantial reduction in the sea's water volume (75%) between 1960 and 1995. Consequently, 20 of its 24 endemic fish populations became extinct, resulting in the loss of productive fisheries that used to support 44,000 metric tons of annual harvest and 60,000 jobs. In addition, coastal habitats and wildlife populations are negatively affected by excessive water withdrawals that cause rivers such as the Ganges River in south Asia to run dry (Abramovitz 1996). The impacts of decreased water quantity and quality on aquatic ecosystems illustrate the link between sustainable fishery and water security. Therefore, to assure that current and future human generations will have sustainable, healthy, and productive fisheries, societies worldwide need to increase the value placed on healthy aquatic systems and their fish populations. One option for ensuring this is to protect the habitat needs for fish and to recognize that human needs are advanced when fish populations can command enough freshwater to sustain their lifecycle. However, this cannot be done in isolation from the needs of other sectors of the ecosystem.

Fish Valuation and Water Security for Fisheries

Declaration of the year 2003 by the United Nations General Assembly as "The Year of Freshwater" reveals the importance being ascribed to addressing the issue of stressed freshwater resources internationally (United Nations General Assembly 2000). This growing importance is reflected in some nations' valuation of freshwater resources and healthy ecosystems changing, as shown by a new emphasis on ecosystems in laws at all levels of governance systems, local to global. These laws include the 1972 Clean Water Act in United States and the adoption of a new national water policy in South Africa that aims to meet the freshwater needs, quantity and quality, of ecosystems (Postel 2002). Moreover, in the United States, growing opposition by a segment of the public against large water projects that alter aquatic ecosystems, increasing public awareness of the importance of conserving these resources, and growth of the environmental movement since the late 1960s also indicate that water resources are increasingly valued by society (Gleick 2000).

The value attributed to water security for ecosystems and fisheries has changed over time and varies within and across nations. This shift in value has been observed during the early 20th century in the United States, where it was thought that every drop of water should be captured and put to use serving human needs and desires. Leaving some of the water to fulfill ecosystem-related water needs was considered wasteful (Cohen 1970). This perception, dominant prior to the mid-1960s, was likely related to the reliance of the United States' economy on the water-dependent sectors such as mining, manufacturing, agriculture, and hydropower (Grant 1987). By the mid-1960s, however, the perspectives for economic valuation of water began to shift, and

Americans placed greater importance on environmental resources for recreational uses, fish and wildlife habitat, and esthetics (Hoffman-Dooley 1996; Grant 1987). Regardless of how or why a society's value may have changed over time, the current perspective of a nation and the approaches used by its society to assure water security will depend on the comparative value that the public and their decision makers place on their fishery and freshwater resources.

Malawi

Malawi is a developing country with a relatively small per capita gross domestic product of US$600 (CIA 2003). Its population, as of 2003, consists of 11.6 million people with a growth rate of 2.21% (CIA 2003). The value of fish and fish products is relatively high among Malawians primarily due to their dietary reliance on this protein source and to its importance in employment and commerce of local communities (Dobson 1999). However, a variety of factors coalesced to cause a rapid and severe decline in fish production during the early 1990s (Wilson 2004). Increasing human population growth, fishing gear improvements, and incursion by neighboring fishers were some of the reasons for increased pressure on the fisheries in Lake Malawi. In addition, extreme droughts alternating with torrential rains led to poor crop production during the 1980s and 1990s, causing many desperate farmers to move into fishing, which further increased the fishing pressure. The decrease in fish production had dramatic negative impacts on the health of the population as Malawians were forced to reduce their fish consumption by almost 50% during the late 1990s and early 2000s (Wilson 2004).

Government and aid donors responded to the crisis in several ways. One response was an increased focus on water security for the health of fish populations and ecosystems. A part of this response focuses on water degradation taking place due to increased sedimentation caused by deforestation. Loss of 40% of Malawi's forest cover has led to soil erosion and associated sediment loading increases in water bodies. Input of untreated sewage water from local communities also poses a problem, especially in urban areas. These impacts result in the reduction of water quantity and quality and fish habitat (Department of Environmental Affairs 1998). Additionally, the public and government have focused on harvest regulation and improving overall ecosystem health. These actions have included implementation of national legislation and policy, such as the 1994 National Environmental Action Plan, which is updated biannually, the 1996 Environment Management Act, the 1997 Fisheries Conservation and Management Act, and the 1998 Forestry Conservation and Management Act, as well as joining in a number of international environmental agreements.

China

China, as illustrated by the case study below on the Yangtze River, relies on its water resources for agriculture (88%), industry (10%), and domestic (2%) uses (Moore 1989). The Yangtze River in China is a crucial resource to the livelihood of its inhabitants and to the economic growth of the nation. It is a main waterway for commercial shipping, with 570 million tons of cargo transported between 1996 and 2000 (Navigation Management Bureau of the Yangtze River, no date). Moreover, this river is important for other human-related uses as it provided, in 2001, freshwater for agricultural (960 billion m^3 per year) and industrial (18 billion m^3 per year) sectors, and 6 billion m^3 per year of freshwater to more than 450 million domestic users (Ministry of Water Resources 2003).

Human activities have caused substantial impacts on the fishery of Yangtze River. Land-use changes within the watershed have resulted in the conversion of 85% of the land cover from forest to agricultural land during the last 50 years, thus increasing soil erosion and shrinking lake areas and the amount of fish habitat (World Wildlife Fund for Nature China 2002). Concurrently with these changes, large quantities of wastewater from residential, shipping, agricultural, and industrial sectors are being discharged into the Yangtze River with little or no treatment (Ministry of Water Resources 2002; State Environmental Protection Administration of China 2002). Water pollution and overharvesting have further contributed to the huge losses to the Yangtze River fishery (State Environmental Protection Administration of China 2003), with the number of economically important fish species being reduced from 50 species in the 1950s to 20 species, and fish production has slipped to 20% of the 1960's level (State Environmental Protection Administration, no date). The impact of this degradation on fish population has also been aggravated by the large number of dams and their reservoirs. As of 1995, there were 45,628 reservoirs and associated dams (Li, no date) that block fish migration and impact water quality and quantity resulting in negative impacts on riverine and migratory fish, such as the endangered Chinese sturgeon *Acipenser sinensis* (World Wildlife Fund for Nature China 2002). With the declining wild fish resources, aquaculture production has progressively grown to meet the demand for fish products with 54.4% of all of China's fish harvest coming from aquaculture in 1996 (NOAA 2000). This shift is resulting in aquaculture becoming increasingly important to the national economy as China provides 83.6% of the world's aquaculture production (NOAA 2000). With the degradation of the Yangtze River, and the impact on aquaculture ponds and ecosystem health, the Chinese government has been taking measures to protect the freshwater resources through implementation of laws and regulations.

United States

In the United States, water resources are important for human activities, including agriculture (38%), domestic (5%), and industrial (57%) uses (Moore 1989). Fisheries resources also are important for human activities, including both commercial and recreational fisheries, with the commercial harvest landed within the United States estimated in 2001 as $3,192,878,000 (NMFS 2002) and recreational fishery estimated in 1996 at $37,797,060,000 (Maharaj and Carpenter 2003). In addition to the economic value related to these fisheries, there is a growing interest in the United States for conserving or restoring ecosystem health. The CALFED-Bay Delta program is a promising example of a cooperative venture that attempts to balance the water needs of the ecosystem with those of society.

California's multigovernmental agency CALFED Bay-Delta Program focuses on rehabilitation and protection of ecological processes within the Bay-Delta system. This program is the outcome of decades of competing demands among freshwater users that have stressed the Bay-Delta system, resulting in loss of habitats, water degradation, and the listing of two species of fish under the federal Endangered Species Act (CALFED 1999). Currently, the demands for how freshwater from the Bay-Delta system is allocated are being split among the needs for humans, their economy, and the ecosystem. This includes providing drinking water for 22 million people; irrigation of 45% of the entire nation's fruits and vegetables, a $27 billion agriculture industry, and the needs of the Bay-Delta

estuarine ecosystem, which covers 738,000 acres (Morandi 1998) supporting 80% of the state's commercial salmon fisheries and home to 750 plant and animal species (CALFED 2002). Inclusion of the ecosystem as one of the recognized users of the Bay-Delta system's freshwater highlights the growing importance for assuring that needs of the aquatic ecosystem and its fisheries are considered and met.

Fisheries Valuations and Water Security: China, Malawi, and the United States

Malawi, China, and the United States are reacting to the needs of their societies, albeit differently, in relations to their reliance on their fishery and the valuation of the use of freshwater in local communities. In Malawi, the collapse of the fishery on which its populace relies for a substantial portion of its dietary intake resulted in a strong response by the government to protect fish stocks and local fisheries. In the United States and China, the valuation of freshwater resources for the use of agricultural, industrial, and domestic users is high relative to the needs of the ecosystem and fish communities, although these latter needs appear to be gaining value in recent years. However, to meet the growing demand for fish protein, both countries historically have turned towards technological solutions to enhance fish production in aquaculture enterprises. Currently, some of these enterprises are used to enhance and restore wild fish populations.

The Chinese, U.S., and Malawian governments appear to be making decisions that focus on conserving and restoring water. However, whether these decisions are being made to enhance ecosystem and fish health with an eye towards preserving long-term environmental and economic interests, or merely to improve short-term economic and human activities, is not always clear. In China, the growing importance of aquaculture and continuation of river damming for other human needs brings into question the value attributed to wild fish populations. In the United States, the growth of the recreational fishing industry indicates that some of these decisions are being made to improve some wild fish populations that are economically valuable, while state and federal mandates protect species that are listed as threatened or endangered. Malawi, within the constraints of limited economic and staff resources, is focused on water security to restore fish habitat, safe drinking water, and normal water flows.

Regardless of the intent, there are several international environmental agreements to which these nations are parties, as well as nationwide government regulations in all three countries to regulate freshwater quality and quantity that benefit ecosystems and fisheries. All three are signatories to the 1971 Ramsar Convention on Wetlands in which the parties commit to identifying and listing critical wetlands for their conservation. Examples of national legislation and policy include 1997 Malawi's Fisheries Conservation and Management Act and its 1999 Water Policy that aim to promote fisheries conservation and sufficient water quantity and quality. China's Water Act aims to manage the use of water and protect water resources. China also enacted the 1984 Water Pollution Control Act and the 1986 Fishery Act. In the United States, water quality protection was enacted in 1948 with the Federal Water Pollution Control Act. Now called the Clean Water Act, it was amended and strengthened in 1972, 1977, and 1988. Protection for fish habitat, fish species, and fisheries are found in the 1973 Endangered Species Act, the 1956 (amended 1964) Fish and Wildlife Coordination Act, the 1968 Wild and Scenic Rivers Act, and the 1996 Magnuson-Stevens Fisheries Conservation and Management Act.

Implications for Fisheries Managers

Assuring water security for fish and ecosystems is of utmost importance if fisheries are to be conserved for present and future generations. However, this is not an easy task as society varies globally on the importance (low to high) it attributes to water security for ecosystems and fisheries, as well as in their motivation (food, ecosystem integrity) for assuring this security, and their perceptions can and do change over time based on societal values. To achieve a globally shared perspective that will result in water security for fisheries being considered as important as the water security for human uses, we need to strengthen society's abilities to engage in transdisciplinary and multicultural collaboration that ensures the long-term sustainability of fish populations.

The question, thus, is not whether we can achieve water security for fisheries but, more pressingly, how willing managers are to accept the challenge of changing society's valuation mechanism to provide water security for humans and their allied ecosystems in the context of other emerging global environmental concerns. This challenge will require substantial investment in outreach to educate the public on the importance of water security for fisheries. Once accomplished, managers will also need to resolve the growing disconnect between fisheries and water management agencies and their disparate objectives. This disconnect often results in decisions by one agency conflicting with the goals of others, such as increasing water withdrawal for use by other sectors of society during a critical period for fish populations (i.e., spawning). Last, the lack of knowledge regarding freshwater needs of aquatic ecosystems is problematic (Bergkamp and Pirot 1999; Gleick 2000) as decision makers want to know the minimum quantity and quality of water needed by the ecosystem to assure that it is fully utilized to meet the demands of other sectors. Thus, the risk exists that decision makers will continue to minimize the needs of freshwater ecosystems until water and fishery scientists invest substantial effort to increase our knowledge of freshwater ecosystem needs and their overall integration into societal values and livelihoods. To do otherwise would sacrifice our abilities to provide livable habitats for fish, diminish ecosystem values, and call into question our own existence and abilities.

Conclusion

We cannot point to an easy way for instilling within a nation the valuation of water security for fisheries or for creating an imperative for maintaining instream flows to preserve fish populations and ecosystems; although the international community may play an important role in facilitating the evolution of these values through environmental international agreements. For example, all three nations are parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Ramsar Convention on Wetlands, and International Convention for the Prevention of Pollution from Ships (CIA 2003). The provisions of these treaties contain some incentive for improved freshwater resources and/or associated biota and may serve as the impetus for some of the national legislation directed at freshwater and fisheries resources. Regardless of the source of the impetus, these three nations, as well as other nations worldwide, appear to be heading towards increasing protection for water security for ecosystems and, thus, fisheries. Nevertheless, even with these trends of increasing protection, fisheries managers and other stakeholders need to remain engaged in agenda setting, policy making, and implementation processes so that the trends persist and gain momentum. Such engagement should serve to

garner political support and understanding of the importance of officially incorporating ecosystem and fish population needs for freshwater along with the other three sectors: agricultural, industrial and domestic.

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