POLICY FORUM: ECOLOGY

Managing Water for People and Nature

Nels Johnson, Carmen Revenga, Jaime Echeverria

Growing water scarcity and alarming declines in aquatic biodiversity indicate that water policies in most of the world are failing to protect life's most vital resource. Water is certain to be a major topic of discussion at next year's Rio +10 Summit and seems likely to join climate change as a perennial topic at global gatherings of environmental policy-makers. Two questions should be prominent at these events. First, where is water scarce and how will this change over time? Second, what changes in water management can address the needs of people and nature?

How Scarce Is Water?

Freshwater ecosystems occupy less than 1% of the earth's surface but deliver goods and services of enormous global value. Inland capture fisheries, for example, contribute about 12% of all fish consumed by humans (*1*). Irrigated agriculture supplies about 40% of the world's food crops (*2*), and hydropower provides nearly 20% of the world's electricity production (*3*). An estimated 12% of all animal species live in freshwater ecosystems, and most other species depend in some way on freshwater ecosystems for their survival (*4*).

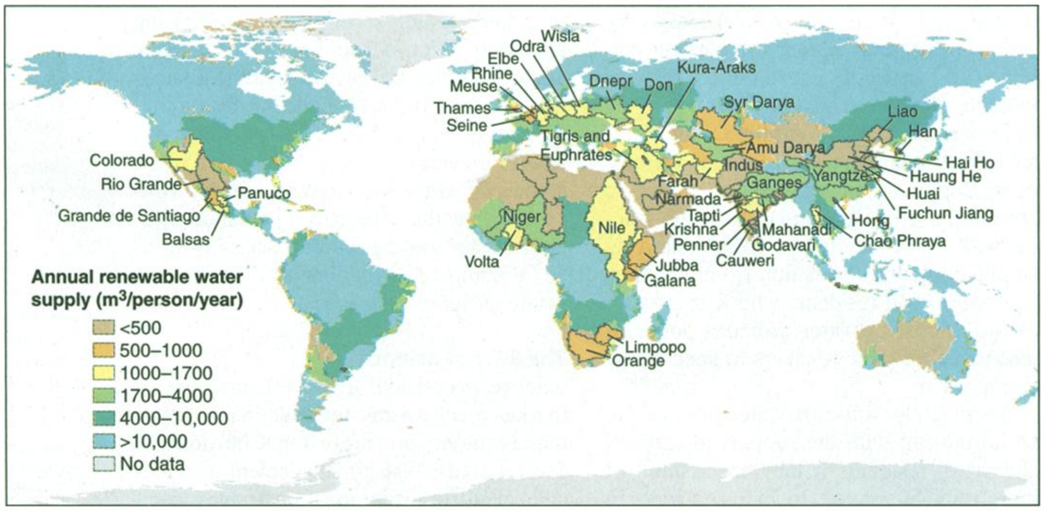
Despite their value, freshwater ecosystems are being intensely modified and degraded by human activities. Since 1950, the number of large dams (over 15 meters in height) has increased from 5700 worldwide to 41,000, creating extensive habitat fragmentation in nearly 60% of the major river basins (*5*). So much water is diverted for human uses that the natural flow of major rivers such as the Colorado, Yellow, and Amu Darya no longer reach the sea during the dry season (*6*).

Compared with domestic and industrial water uses, agriculture has a disproportionate impact on water flow, water quality, and alteration of freshwater habitats. About 70% of all water withdrawals are for agriculture (*2*), but more than half the water entering irrigation distribution systems never makes it to the crops because of leakage and evaporation (*6*). As population grows, we will become even more dependent on irrigation for our food supplies. This places extraordinary stress on freshwater systems particularly in arid and semi-arid regions.

New estimates of water scarcity calculated by the World Resources Institute in collaboration with the University of New Hampshire show that 2.3 billion people live in river basins under water stress, with annual per capita water availability below 1700 m^3. Of these, 1.7 billion people reside in highly stressed river basins where water availability falls below 1000 m^3 per capita annually, and chronic water shortages threaten food production and hinder economic development (*7*). Assuming that current consumption patterns will continue, at least 3.5 billion people will live in water-stressed river basins in 2025—or 48% of the world's projected population (see the figure) (*5*).

Water is not only becoming scarce because of increased demand, but also because of higher pollution levels and habitat degradation. Contamination denies as many as 3.3 billion people access to clean water supplies (*5*). In developing countries, an estimated 90% of wastewater is discharged directly into rivers and streams without treatment (*2*), and in many parts of the world, rivers and lakes are so polluted that their water is unfit even for industrial uses (*2*). A century ago, the main contamination problems were fecal and organic pollution from untreated human waste and industrial byproducts. These pollution sources have been greatly reduced in most industrialized countries. However, a new suite of contaminants from intensive agriculture and urban development has kept the cleanup from being complete. Meanwhile, in most developing countries, traditional pollution sources and new pollutants like pesticides have combined to heavily degrade water quality near urban centers and intensive agricultural areas (*8*).

Concerns about water scarcity also include groundwater sources. Nearly 1.5 billion people rely on groundwater as their sole source of drinking water (*9*). Some of this water comes from deep sources that are isolated from the normal runoff cycle, but much groundwater comes from shallower aquifers that draw from the same runoff that feeds freshwater ecosystems. Overdrafting of groundwater sources can rob streams and rivers of a significant fraction of their flow, whereas pollution can render aquifers unfit for human use and degrade water quality in adjacent freshwater ecosystems.



Projected renewable water supply by river basin, 2025. Outlined basins are projected to have at least 10 million residents by 2025 and are in or approaching water scarcity, with less than 2500 m^3 of water per person per year. Source: (*5*).

CREDIT: WORLD RESOURCES INSTITUTE

Can We Manage Water for People and Nature?

Freshwater ecosystems are not being managed effectively for people or for nature. The state of aquatic biodiversity is far worse than for forest, grassland, and coastal ecosystems (*5*). The rapid proliferation of dams has caused widespread loss of freshwater habitats, especially waterfalls, rapids, riparian floodplains, and wetlands (*10*). Large dams such as Egypt's

The authors are at the World Resources Institute, Washington, DC 20002, USA

Aswan, for example, may alter aquatic and riparian habitat conditions for more than 1000 kilometers downstream. Floodplains and wetlands have also been greatly diminished by river and stream embankments for navigation and flood control. More than half the world's wetlands have been converted to other uses, especially agriculture, during the 20th century (*5*). As a result, more than 20% of the world's freshwater fish species have become extinct, endangered, or threatened in recent decades (*11*). Researchers estimate future extinction rates for aquatic animal species in North America could be five times as high as for terrestrial species (*12*).

A major reason for growing water scarcity and freshwater ecosystem decline is that water is undervalued the world over. For example, the price for irrigation water usually covers only a small fraction of capital and management costs as governments pursue policies for cheap food production. Moreover, the costs of watershed management have been almost universally neglected in water pricing. Meanwhile, pollution continues to grow, because regulations are often ineffective, and polluters are rarely charged for damages caused by their effluents. Equitable market-oriented mechanisms are an essential part of the solution.

A first step toward sustainable water management is to improve efficiency by setting prices that reflect the cost of supplying and distributing water. Price reforms in Chile reduced irrigation water use by 22 to 26% and saved $400 million in new water infrastructure costs while price increases in Bogor, Indonesia, reduced domestic consumption by 30% (*13*). Although pricing water to reflect its true cost is relatively simple in theory, opposition from irrigators and poor urban residents who fear increases in the cost of water provides powerful incentives for policy-makers to keep subsidizing water.

Fortunately, full-cost water pricing can be introduced with the support of farmers and urban residents if they are assured of more reliable service. In India, farmers in Andhra Pradesh agreed to a threefold increase in water prices as part of a reform package that increased their role in the governance of the irrigation agency and its use of their fees (*14*). In Haiti, shantytown residents with no connection to the water utility pay 10 times as much for water from private water trucks as those who are connected in nearby villages (*15*). Water pricing schemes, however, must take the concerns of the poor seriously. The use of progressive block tariffs with a very low initial tier, such as those recently introduced in South Africa, can address social equity concerns (*16*).

A second step is to include the cost of integrated watershed management in the price of water. Ecosystems and land uses influence water flow and water quality in a variety of ways. Wetlands store runoff, recharge aquifers, and digest organic wastes, for example, while forests shade streams, reduce runoff through evapotranspiration, and help to reduce erosion. However, watersheds are routinely ignored in water management. Conserving natural forest and wetland habitats, creating buffer zones along rivers and streams, shifting away from farming and road-building on steep slopes, and avoiding agricultural chemical use in sensitive areas can help achieve water management objectives. This could increase water fees (*17*), but it may also lead to substantial long-term savings. For example, several cities in the United States (including Portland, OR, New York, NY, and Portland, ME) found that every $1 invested in watershed protection could save from $7.5 to nearly $200 for new water treatment facilities (*18*).

A third step toward sustainable water management is to charge polluters for their effluents. A variety of tools are available, including permit fees, discharge levies and fines, and "green" taxes. Similar taxes have been used effectively to reduce CO_2, NO_x, and SO_2 emissions in some European countries (*19*). Where emission levels are tightly regulated, trading schemes are a promising approach. "Nutrient trading," for example, allows factories and sewage treatment facilities to meet their obligations by paying farmers to reduce their effluents, which can lead to greater reductions at less cost. Case studies in Michigan, Wisconsin, and Minnesota show that removing a pound of phosphorous by trading would cost as little as $2.90 compared with almost $24 with conventional approaches (*20*).

The Role of Science

Science is essential to the effective use of market mechanisms for sustainable water management, but more must be done in several areas. Water management agencies and scientific institutions must invest carefully in more basic and applied research, especially in water-stressed river basins. Better knowledge about such issues as minimum in-stream flows for maintaining biodiversity, maximum threshold loads for common pollutants, and the relation of land use to hydrologic functions is especially important. The World Water Assessment Program and the Millennium Ecosystem Assessment, both sponsored by the United Nations, provide important frameworks for scientists to address such issues (*21*). In addition, governments and donor agencies must reverse the worldwide decline in water monitoring. The number of monitoring stations for water flow and quality in Africa, for example, declined by 90% between 1990 and 2000 (*22*). Future international water meetings should highlight this issue and develop monitoring guidelines for use in new water management projects. Scientists can also help by identifying environmental and economic tradeoffs, developing future scenarios, and evaluating management options. This information is crucial if policy-makers and the public are to support policy and management changes, including the use of market mechanisms, needed to sustain freshwater ecosystems.

References and Notes

1. FAO, *Review of World Fisheries and Aquaculture 1998* (Food and Agriculture Organization of the United Nations, Rome, 1999).
2. WMO, *Comprehensive Assessment of the Freshwater Resources of the World* (World Meteorological Organization, Geneva, 1997).
3. P. H. Gleick, *The World's Water 1998–1999* (Island Press, Washington, DC, 1998).
4. J. Abramovitz, "Imperiled waters, impoverished future: The decline of freshwater ecosystems" (World Watch Paper 128, Worldwatch Institute, Washington, DC, 1996).
5. C. Revenga *et al., Pilot Analysis of Global Ecosystems: Freshwater Systems* (World Resources Institute, Washington, DC, 2000).
6. S. Postel, *Where Have All the Rivers Gone?* (Worldwatch Institute, Washington, DC, 1995).
7. M. Falkenmark, C. Widstrand. *Popul. Bull.* **47**(3), 1 (1992).
8. I. A. Shiklomanov, *Comprehensive Assessment of the Freshwater Resources of the World* (World Meteorological Organization, Geneva, and Stockholm Environment Institute, Stockholm, 1997).
9. UNEP, *Groundwater: A Threatened Resource* (U.N. Environment Program, Nairobi, Kenya, 1996).
10. C. J. Vorosmarty, D. Sahagian, *BioScience* **50**, 753 (2000).
11. P. B. Moyle, R. A. Leidy, in *Conservation Biology: The Theory and Practice of Nature Conservation, Preservation and Management*, P. Fiedler, S. Jain, Eds. (Chapman & Hall, New York, 1992), pp. 127–169. Others, such as A. Brautigam [*World Conserv.* **30**(2), 4 (1999)], believe that this is a major underestimate.
12. A. Ricciardi, J. B. Rasmussen, *Conserv. Biol.* **13**, 1220 (1999).
13. M. Rosegrant *et al., Food Policy* **20**(3), 203 (1995).
14. B. Ramesh, Summary of water and economics session, Second World Water Forum (www.worldwaterforum.org, 2000).
15. P. Constance, *IDB America* **26**(7–8), 2 (1999).
16. WRI, *World Resources 2000–2001: People and Ecosystems: The Fraying Web of Life* (World Resources Institute, Washington, DC, 2000).
17. R. Solórzano *et al.* [*Valoración Económico Ecológica del Agua* (Tropical Science Center, San José, Costa Rica, 1995)] found that water rates in Costa Rica should increase from 20 to 50% to cover cost of watershed protection and management.
18. W. V. Reid, in *Managing Human Dominated Ecosystems*, G. Chichilnisky, G. C. Daily, P. Ehrlich, G. Heal, J. S. Miller, Eds. (Monographs in Systematic Botany from the Missouri Botanical Garden, St. Louis, MO, 2001), vol. 84, pp. 197–225.
19. OECD, *Environmental Taxes and Green Tax Reform* (Organization for Economic Cooperation and Development, Paris, 1997).
20. P. Faeth, *Fertile Ground: Nutrient Trading's Potential to Cost-Effectively Improve Water Quality* (World Resources Institute, Washington, DC, 2000).
21. See www.unesco.org/water/wwap/ and www.millenniumassessment.org
22. C. J. Vorosmarty *et al., Eos* **82**(5), 54 (2001).

23. We thank A. Janetos, D. Tunstall, B. Alwyard, and C. Vorosmarty for their helpful comments.