Institute on Science for Global Policy

Managing Water for People and Fish, Now and in a Changing Climate**

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Summary
Recent drought has exposed limitations and flaws in California's water management for humans, aquatic ecosystems and fish. With climate change, these problems will only get worse. Going forward, sustainable water management must consider the functional connections between the environmental water sources used by humans and healthy aquatic ecosystems. We need to acknowledge the limits to our water supplies and, because current demands exceed sustainable environmental supplies, develop and implement plans to meet our human needs with less water. Science has already provided much of the information we need for improved management and aquatic ecosystem protection, but its application in policy has been hampered by disagreement, denial, and political inertia. Additional scientific opportunities exist for developing and applying regional water budgets, and for using improved models to evaluate alternative management scenarios. New policies are needed to reprioritize allocation of water resources to better protect aquatic ecosystems, accommodate the functional realities of our hydrologic system, encourage conservation and efficient use of water, and promote water management practices that increase water supplies without further damaging our already stressed aquatic ecosystems.

Current realities
California's recent multiyear drought has revealed unwelcome — but not unforeseen — limitations and flaws in our current management of water, fish, and aquatic ecosystems. The state's approach to cope with the dry conditions and maintain stable water deliveries to farms and cities by increasing water diversions from rivers and draining surface reservoirs and underground aquifers is unsustainable, now and in a warmer and potentially drier future. Not only did it fail to meet demands for human use, it drove aquatic ecosystems and native fishes, already stressed by decades of water management practices, pollution, habitat degradation, and other related stressors, to collapse. Scientists now predict imminent extinction of several fish species long considered biological indicators of healthy aquatic ecosystems (Figure 1C).

Water, aquatic ecosystems, and fish are all public trust resources in California, managed by the state for public use. Our recent experience confirms that current policies and management are not meeting these public trust responsibilities, particularly for aquatic ecosystems and fish. New policies based on a clearer understanding of the functions, requirements, and limits of these resources are needed. Four foundational, intersecting realities — true for California and nearly everywhere else on the planet — govern sustainable management of fresh water, aquatic ecosystems, and the fish and wildlife that rely on them.

First, most water resources used by humans come from the environment, from rivers, lakes, wetlands, underground aquifers, and even the ocean. All of these water sources are connected by the hydrologic cycle: weakening or breaking the hydrologic connections among them impairs their functional availability to humans as water sources as well as their value as habitats for fish and wildlife. For example, excessive diversion of water from a river reduces flows, degrades riverine and adjacent wetland ecosystems, decreases recharge of connected aquifers, and impairs both water quality and the capacity of these ecosystems to provide the natural filtration services that protect water quality. Similarly, excessive groundwater pumping that depletes an aquifer can lead to land subsidence, reduced aquifer storage capacity, and flow reductions in connected rivers, all of which can decrease surface water supplies and ecosystem functionality.

Second, water from the environment is a finite supply that varies from year to year. This supply is not a function of human water demands, but is instead dependent on what is provided through rain, snow, and the equally finite, if somewhat less variable, water supplies in surface and underground reservoirs. However, aquatic ecosystems and fish rely on that same water for river flows and wetland inundation that create habitat and drive essential ecological processes. Excessive water diversions from the environment, which can create chronic drought conditions in aquatic ecosystems, will not support healthy fish and wildlife populations (Figure 1).

Third, all evidence indicates that we — in California and many other regions around the globe — are currently living beyond our water means. Collapsing aquatic ecosystems, fish population declines, deteriorating water quality, water shortages, and depleting aquifers all point to mismanagement and overconsumption of our finite and interconnected water resources.

Finally, the impact of climate change on precipitation, air temperatures, and sea level are expected to significantly affect both environmental water supplies and water needs of humans and ecosystems. In California, predicted declines in mountain snowpack have implications for river ecosystems, cold water flows for salmonid fishes, reservoir operations, flood control, and management of increasingly volatile surface water supplies for human use and environmental protection. Downstream, where local farms and government water facilities divert water for irrigation and urban use, sea level rise will require increases in river flows to prevent salt water intrusion and preserve water quality, with resultant impacts on upstream water supplies.

Scientific opportunities and challenges

There is already a rich body of scientific literature on water requirements for aquatic ecosystems and fish, including for California's rivers and estuaries. Both regulatory agencies and academic researchers have studied and credibly defined the amounts of water required to protect aquatic ecosystems and fish. However, application of these results is mired in controversy between stakeholders with different interests and regulators who are not immune from political pressure. Several areas of scientific opportunity and/or challenge that flow from the current realities could help inform and advance these and other needed policies.

Managing water is like managing a budget. In California (and many other parts of the globe), we need better quantitative information on our water budget realities. At appropriate regional scales, we need to know: (i) the types and amounts of water supplies, including local surface water, imported water, groundwater, and recycled or desalinated water; (ii) the types and amounts of demands for that water, including for a healthy environment; (iii) whether the supply and demand are in balance and the amount of the deficit (or surplus); and (iv) the opportunities for increasing supply and reducing demand to bring an unbalanced "budget" into balance.

Models can be powerful tools to investigate relationships among multiple variables and alternative scenarios. California water managers use several sophisticated models to evaluate and plan operations of the state's complicated water system. However, most of these efforts focus on a subset of the water resources (e.g., surface water but not groundwater), produce narrowly targeted outputs such as maximizing annual water deliveries, rarely consider effects on ecosystems or species, and incorporate very conservative climate change projections. These approaches are not sufficient to guide sustainable management of water, fish, and aquatic ecosystems now or in our changing world.

The application of science to natural resource management and public policy is rarely simple. It is particularly difficult for issues such as water in California (or other places), which involve competing needs for limited, already over-allocated resources in naturally dynamic and changing systems. Properly defined, science-based decision support tools that integrate research and modeling results from multiple disciplines (e.g., biology, hydrology, economics, climate science) can guide and provide transparency to the process and serve as a framework for effective adaptive management to refine and improve our management over time.

Policy issues

For sustainable water management in a changing climate, the greatest challenge for policy makers is not scientific — managing water is, in the end, a mass balance equation. The real challenges are in acknowledging and securing public recognition of the limits of hydrological and ecological systems, prioritizing choices about allocation of the limited resource, and promoting approaches that increase the size of the water supply while preserving our other public policy objectives. Meeting these challenges will require informed engagement of the public and stakeholders and new policies and action by government agencies at all levels that:

- Prioritize allocation of water resources to provide (i) safe drinking water for people; (ii) environmental flows for ecosystem health and hydrological services; and (iii) water for economic uses based on revisions of existing water allocations that correct over-allocation. Such prioritization, and particularly the rebalancing of environmental and economic uses of water, requires changes at all levels of government, including to state law for water use, state and federal regulations for ecosystem, fisheries, and water quality protection, and state, federal and local water contracts.

- Regulate and manage surface and groundwater resources as integrated water supplies throughout government (i.e., federal, state, and local water agencies). Specifically restrict activities that impair hydrologic connectivity (e.g., floodplain development) and manage floods to enhance floodplain habitat creation and groundwater recharge (e.g., by the U.S. Bureau of Reclamation, Army Corps of Engineers, Federal Emergency Management Agency, and related state and local planning agencies).

- Plan for hydrological variability rather than responding to floods and droughts as extreme events. Manage environmental water for multiyear ecosystem protection and water supply reliability instead of maximum annual deliveries, promote realistic expectations by basing permitted or contractual water allocations on projected supplies in dry years rather than wet years, and develop specific plans for ecosystem protection and water supply management during droughts throughout government agencies.

- Protect water quality by reducing or eliminating point and nonpoint source pollution (e.g., agricultural and stormwater runoff, underground injection of contaminated wastewater) and by protecting and restoring habitats that provide water quality-related ecosystem services throughout governmental agencies (e.g., Environmental Protection Agency, State Water Resources Control Board, and agricultural and urban discharge and stormwater management districts).

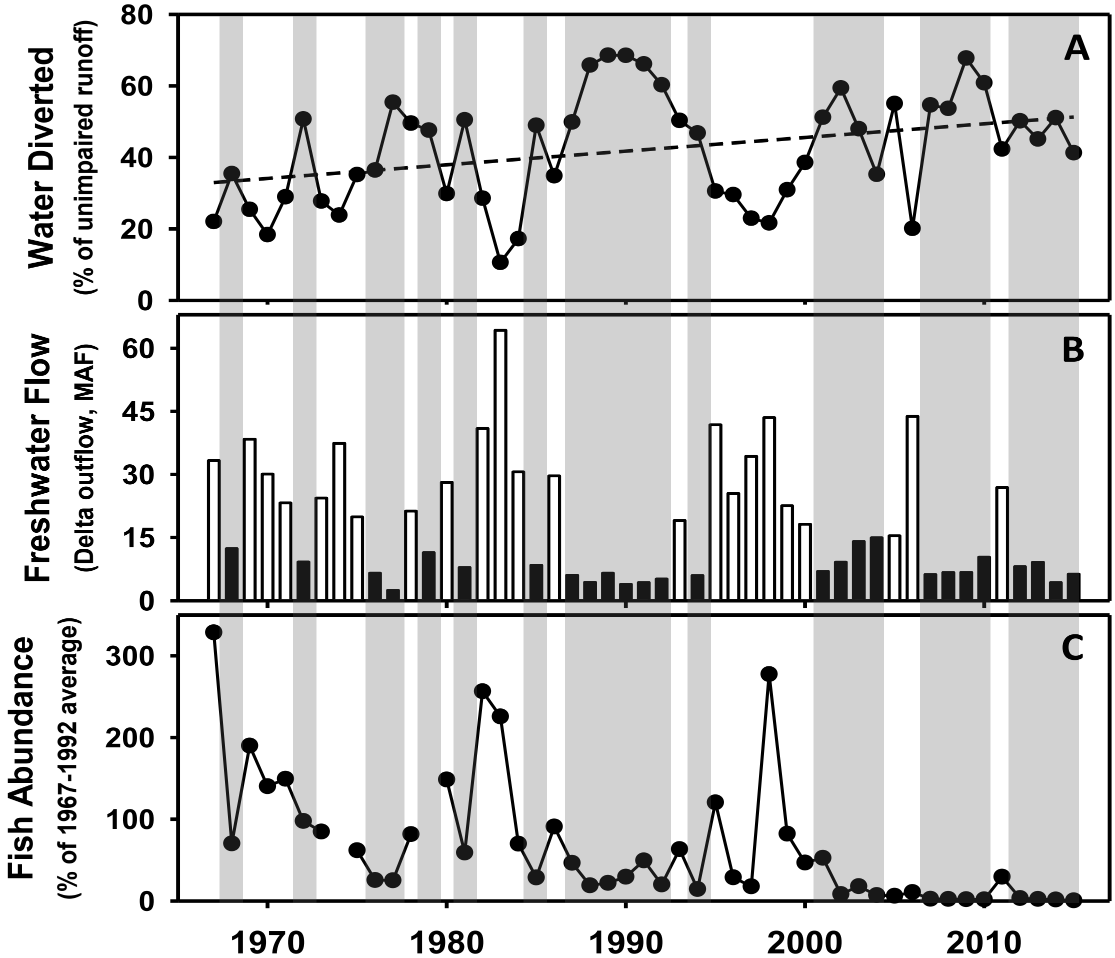
- Require and/or incentivize water use efficiency and water conservation by urban and agricultural water users using strategies such as “tiered pricing” and “demand reduction” in all water year types (i.e., both wet and dry years).

- Promote implementation of storm and rainwater capture, water recycling and reuse, and green infrastructure to increase local water supplies, reduce pollution, and recharge local groundwater basins (state and local agencies and water districts).

References

Richter, B. (2014). Chasing water: a guide for moving from scarcity to sustainability. Island Press.

Figure 1



Increasing water diversions from California's Sacramento-San Joaquin watershed and Delta have reduced freshwater flow into the San Francisco Bay, creating chronic, man-made drought conditions in the estuary and upstream, degrading aquatic habitat and driving many fish species toward extinction.

A. Annual water diversions from the Sacramento-San Joaquin watershed and Delta, expressed as the percentage of estimated unimpaired runoff (i.e., without dams or water diversions). Diversions have increased by 30%, from an average of 37% of unimpaired runoff in the 1970s to an average of 49% of unimpaired runoff in the past decade. Diversion rates are highest in years with median and dry hydrological conditions.
B. Annual freshwater flow into the San Francisco Bay estuary, in million acre-feet. Years in which annual flows were less than would have occurred in the driest 20% of years under unimpaired conditions (i.e., natural drought) are shown as black bars and highlighted in gray across the three plots. Based on annual freshwater inflows, the estuary has experienced drought-like conditions in 12 of the last 15 years (80% of years).
C. Abundance of delta smelt, longfin smelt, splittail and striped bass, expressed as the percentage of their average 1967-1992 abundances. Declines in abundance of these estuary-dependent species correspond to low freshwater inflows (gray highlight). Average abundance for the last 4 years was 2% of 1967-1992 levels. Prolonged low flow conditions have driven populations of these species to such low levels that their capacity to recover when conditions improve is substantially reduced.

Data sources: CA Department of Water Resources (Dayflow and Central Valley Unimpaired flow datasets) and CA Department of Fish and Wildlife (Fall Midwater Trawl Survey).