Dam choices: Analyses for multiple needs

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Environmentalists often go to great lengths to block the construction of new dams because dams interfere with fish migration, inundate terrestrial habitats, and interrupt natural flows that are necessary for critical ecosystem processes. However, few environmental issues are so simplistically black and white, and dams are no exception. Dams can be an important source of clean energy and for poor nations such as Laos or Cambodia, hydropower is an export that can be a foundation for poverty alleviation. The right question is not how to prevent construction of any new dams, but rather what the optimal portfolio of dams is for meeting our energy and fisheries needs while also securing as much biodiversity insurance as possible for our changing world. Ziv et al. (1) from Princeton University and the World Fish Center in Cambodia ask that right question. Specifically, they combine an ingenious model of fish migration in the mainstem Mekong River and its tributaries with scenarios of new dam construction to identify optimal dam deployments throughout the Mekong tributaries (1).

The Mekong River is one of the world's last great rivers to remain largely undammed. However, this will not be true for long, as China launches eight hydropower projects in the upper Mekong where there is a lot of energy to be tapped as the river drops 4,000 m in elevation from its headwaters in Tibet to the China–Laos border (2, 3). Even more troubling to environmentalists are the dams being considered for the lower Mekong tributaries and mainstem. At stake are some of the world's most productive inland fisheries—fisheries that depend on migratory fish species, including some spectacularly unique species as the migratory goonch catfish (*Bagarius yarrelli*), which can reach 0.5 m in length and 65 kg (2). To date quantitative analyses have focused either on the potential damage to species and fisheries from dams or on the energy and economic yields of hydropower. Although everyone admits there are trade-offs, formal analyses of those trade-offs have been lacking. This is where Ziv et al. step in. They frame the question as an optimization problem, where one seeks to maximize the migratory fish biomass while meeting some specified energy demand. This is a numerically rich problem because there are 11 possible mainstem dams and 27 possible tributary dams whose fates are yet undetermined.

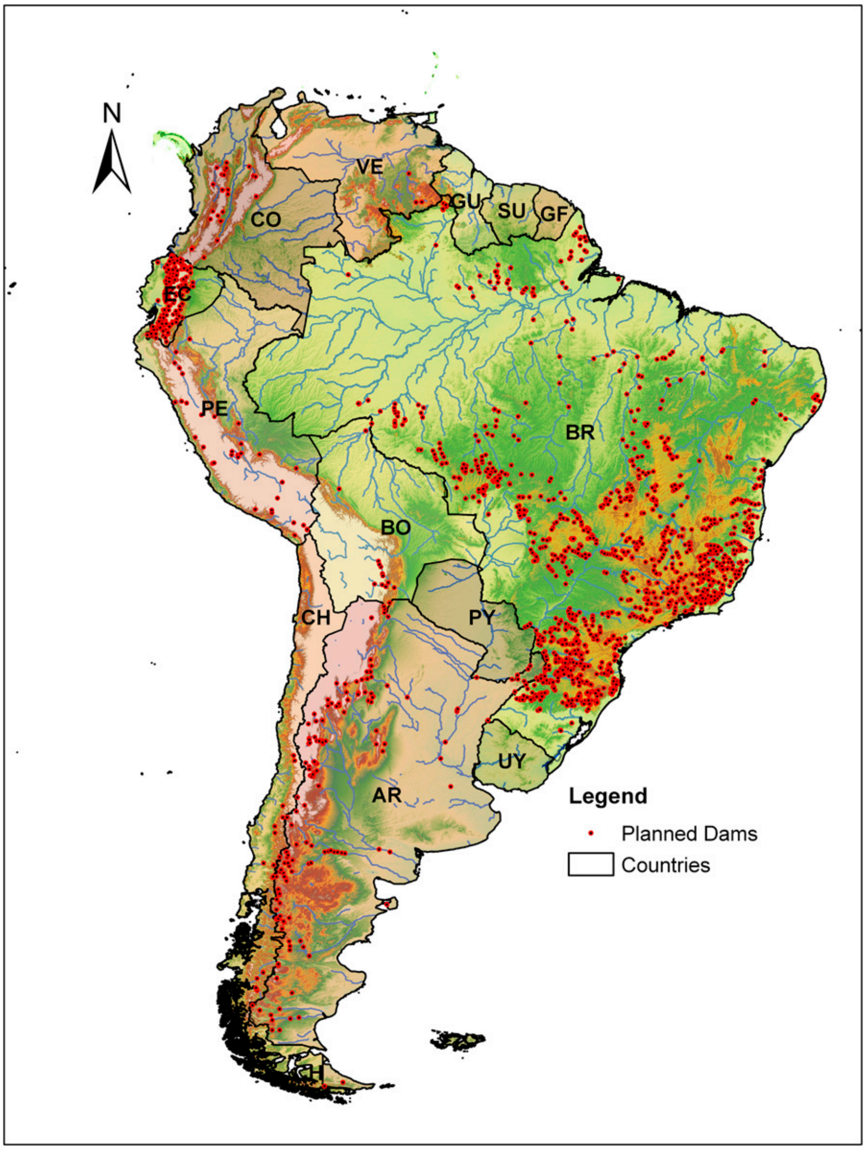

Fig. 1. Proposed hydropower dam projects in South America compiled from each country's ministry of energy and/or planning agency between 2009 and 2011. The original data come from both online databases and official energy strategic plans. Data were compiled by Paulo Petry of The Nature Conservancy. In total 2,215 projects make up this planned hydropower expansion, which entail adding dams to 673 free-running rivers that are currently free of dams and adding dams to 388 rivers already dammed.

Considering just the tributary dams, there are 2^{27} possible permutations of dams for which one can calculate energy yield and fish reductions.

One of the big surprises from their analyses is that although most attention has been given to dams proposed for the mainstem of the lower Mekong, in fact the construction of all of the tributary dams would produce less energy and reduce fish biomass and diversity far more than the construction of six upper mainstem dams. Whenever environmentalists scrutinize hydropower projects, they invariably focus on mainstem dams because dams on the mainstem block a large portion of a river

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basin's flow. The analyses performed by Ziv et al. reveal that tributary dams could potentially have massive consequences for food security in the region, yet generate much less energy than mainstem projects. They then explore in depth the suite of possible choices, taking into consideration the 27 tributary dams whose fate has not yet been decided. What they learn is that it is possible to make either very wise or very poor choices regarding which hydropower projects are selected to meet any given energy requirement. This dilemma can be quantified by the loss in fish biomass per each additional terawatt hour gained by one's hydropower choices. Depending on which tributaries are dammed, this trade-off varies by a factor of 4. Clearly the smart choice is to select hydropower projects that cause the smallest migratory fish reductions. Although the numerical calculations and sensitivity analyses conducted by Ziv et al. would likely seem complicated to most decision makers, the results can be notably clear and unambiguous. For example, it is possible to identify particular proposed dams that are extremely harmful to fish and that can be avoided yet still meet energy demands. That solution is science-driven practical conservation and development.

The Mekong story is a global story, being played out in rivers around the world. For example, in South America there are 2,215 hydropower projects planned, which entail adding dams to 673 rivers that are currently free of dams and adding dams to 388 rivers already dammed (Fig. 1). Morevoer, wherever these dam projects are planned, there are issues of food security for downstream human populations (4). Floodplain fisheries average 200–2,000 kg of fish production per year. When dams cut floodplains off from their natural flows, this production is severely reduced and puts at risk the millions of people dependent on floodplain fisheries and agriculture. Conservative estimates are that the world's existing dams impact the food securtiy of nearly 0.5 billion people worldwide (4). These impacts arise because dams cut off migratory fish movement, eliminate floods that make possible floodplain agiculture and grazing systems, and can cut off nutrients that nourish fish nurseries. Of course these same dams deliver benefits as well—they provide irrigation for upstream agriculture, fisheries may develop in reservoirs, and life-threatening floods may be reduced. It is not a simple matter of dams being good or bad. This conundrum means that all around the world there is a need for analyses such as those conducted by Ziv et al., analyses in which trade-offs between benefits or natural services to humans can be quantified and balanced.

Decisions about hydropower should always be framed as trade-offs among multiple objectives.

Ziv et al.'s contribution sets the stage for a wide variety of elaborations and new analyses. First, in addition to the purely economic or production-oriented trade-offs, it would be useful to combine Ziv et al.'s analyses with an identification of which people may lose their livelihoods. This task is particularly important because it is often the politically powerless and poorer people whose food is cut off to provide energy for wealthier customers. Second, decisions about hydropower should and increasingly do entail potentially removing existing dams as well as deciding where new dams might be constructed. Dams have a finite life span and they become a risk as they age. In addition, the value of a dam for energy production can change as other dams are built along the same river or as new energy sources arise. Thus, in some cases it can make economic and environmental sense to remove dams. The removal of two dams on the Penobscot River in Maine is expected to restore a cultural legacy to the Penobscot Indian Nation, help recover an endangered salmon species, and provide as many as 200 jobs without a loss in total energy production (5). Elsewhere in the United States, trade-off analyses similar to those performed by Ziv et al. have shown that one could remove 12 dams in the Willamette River watershed (Oregon) and reconnect over half of the river basin while sacrificing <2% of hydropower and water storage capacity (6).

Environmentalists and development agencies alike commonly suffer from a certain myopia, whereby they tend to come at problems from only one angle and one objective. For example, conservationists worry about fish and biodiversity, whereas developers worry about energy and capital for growth. The problem is that unnecessary costs are inflicted by single-mindedly worrying about only biodiversity or only energy development. Decades of decision analysis suggest that solutions developed with a single objective in mind typically perform poorly when assessed against multiple objectives (7).

Decisions about hydropower should always be framed as trade-offs among multiple objectives. Ziv et al. show the way for hydropower vs. fish. In fact, their analysis should really be viewed as an initial assessment nested inside broader choices that also involve trade-offs. If the issue is strictly hydropower vs. food production, one solution may appear optimal, when in fact there are better options available when decision makers consider other energy sources such as natural gas or renewables. These analyses would recognize that fisheries productivity might be irreplaceable, whereas energy sources are more interchangeable. The future of development and conservation lies in conducting analyses such as those pioneered by Ziv et al. and in recognizing that there are multiple pathways to economic development and meeting energy and food needs, with those pathways varying enormously in the trade-offs they entail.

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