ECOLOGY

Threats from India's Himalaya Dams

Ecosystem damage and population resettlements loom, owing to poor planning and impact assessments.

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To meet surging domestic energy demand, provide power to the largest population in the world that lacks electricity (> 400 million people), and reduce rapidly growing CO_2 emissions, the Government of India (GOI) has embarked on a fast-track dam-building program. Over the next several decades, the GOI aims to construct 292 dams throughout the Indian Himalaya, doubling current hydropower capacity and contributing ~6% to projected national energy needs by 2030 (*1*). With the use of coal set to expand, India's total carbon emissions are projected to more than double by 2030 (*2*). New dams can play a dual role, helping to limit emissions while providing power to needy people. But major problems loom. We discuss approaches to these as Himalaya hydropower expands.

Biodiversity Impacts

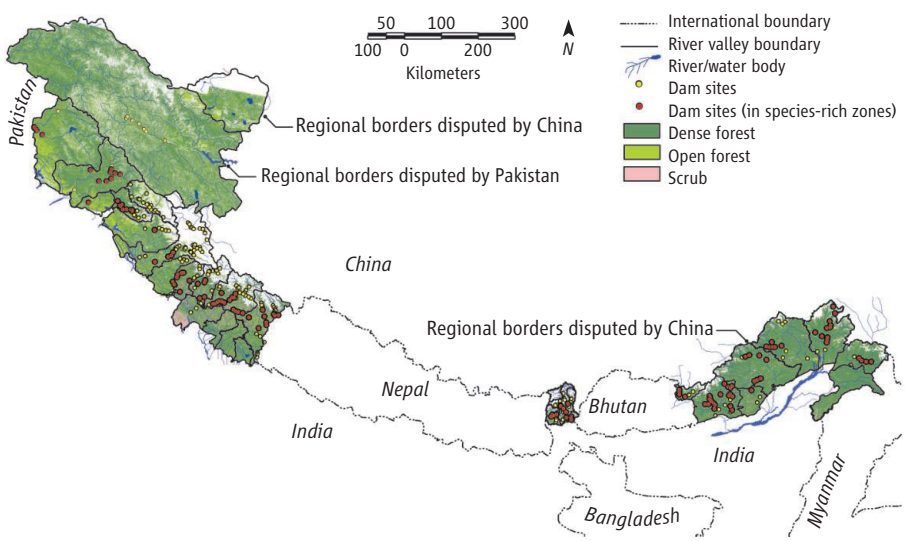
Studies have recognized dam building as the most substantial human impact on riverine ecosystems (*3*). But most studies of ecological effects of river regulation have been carried out in the developed northern hemisphere; such work is largely unknown in India. We assessed impacts and trends of land-use changes from proposed dam building on terrestrial biodiversity in the Indian Himalaya (*4*). Of 292 proposed dams, the study assessed 132 for which public data were available, ranging from 7 to 11,000 MW in size. Of these, 90% would be run-of-the-river dams without storage reservoirs, yet this would not change the impacts highlighted below.

If all dams are constructed as proposed, in 28 of 32 major river valleys, the Indian Himalaya would have one of the highest average dam densities in the world, with one dam for every 32 km of river channel. Proposed locations of dams correlate with zones of species richness for angiosperms, birds, fishes, and butterflies. In the Indian Himalaya, subtropical and temperate forests are most vulnerable to species losses driven by land-use changes (*5*), yet 88% of proposed dams are located in these ecosystems (see the figure). Over half of the dams would be in dense, relatively undisturbed forests. Forest loss due to direct submergence and habitat degradation from dam building could lead to loss of 22 angiosperm and 7 vertebrate taxa by 2025 (*4*). This conservative estimate did not consider effects of habitat fragmentation or isolation on multiple endemic species, general infrastructure development (such as smaller hydro projects and roads), or climate change.

Weak Laws and Practices

Since 1994, India has had a national environmental impact assessment (EIA) law with specific provisions to address threatened and endangered species, protected areas, and other biodiversity concerns. Each state where proposed water resource development projects are located carries out initial planning with GOI oversight (*6*). States then implement EIA provisions after federal approvals. However, there are problems with using inadequate baseline data, monitoring of compliance with EIA protocols, and weak enforcement of sanctions when compliance is poor (*7*, *8*). For example, states have approved projects before mandatory public hearings were held (*9*). The EIA process has already proven to be inadequate to address cumulative impacts from single dams (*10*). More important, for dam construction at the scale proposed in the Indian Himalaya, no cumulative effects analyses are legally required in EIAs, including cascade effects of multiple hydropower projects in a single river basin. Recent reviews have recommended reductions in dams even without including analysis of sediment load changes, road construction, climate change, and livelihood impacts (*11*, *12*). The GOI has not followed these recommendations. Given this history and the scale of proposed hydropower development, it is doubtful that EIA law as currently implemented can adequately address nearly 300 new dam proposals.

Because of high population density and the GOI's historical commitment to hydropower, dams have displaced Indian citizens for decades. GOI figures on how many people have been displaced are difficult to access. Estimates range from 16.4 to 40 million; only China has displaced more people by dams (*13*). Although a national resettlement statute has existed since 2004, Indian resettlement law suffers from fragmented division of responsibilities between state and federal regulators. There are no binding provisions to address cumulative social impacts. With mil-



Distribution of proposed dams in the Himalayan states of India. Spatial data from Landsat Enhanced Thematic Mapper Plus (www.landcover.org/data) (30-m resolution) to delineate forest and nonforest land cover, analyzed using Erdas Imagine 9.1 software. Dam site locations are from (*4*). Borders reflect the authors' original map of Indian government proposals. References to disputed regions are added by *Science* to reflect a United Nations map of Southeast Asia (www.un.org/Depts/Cartographic/map/profile/Souteast-Asia.pdf). *Science* does not have a position regarding boundaries and names shown on this map.

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lions of people losing land rights and resettled without adequate compensation, it is easy to understand why demonstrations against dams are an ongoing feature of Indian civil society.

Improving Planning and Implementation

Most of India's proposed Himalaya hydropower projects are not yet built; the country does not have to sacrifice its biodiversity nor inequitably resettle people affected by dams. Yet even before the massive national blackout in July 2012, the GOI has been under intense pressure to increase electricity supplies. Solutions lie with integrating national energy planning and specific hydropower sector reforms.

First, despite the availability of systematic planning frameworks, the GOI has not conducted a countrywide review of future energy and water requirements that considers alternatives beyond hydropower; such a study might reduce the assumed need for so many dams (*14*, *15*). For example, India loses 20 to 30% of total power generated (*16*), an amount greater than all current hydropower production. Reducing these losses, mainly due to poor grid transmission and theft, could help meet GOI hydropower targets out to 2030, likely at less cost. India's ongoing Ganga River Basin Assessment and recently released draft National Water Policy are steps in the right direction, but they say little about hydropower in the Himalaya and make no link between protecting forests and provisions of water resources (*17*, *18*).

A second action would be improving India's EIA process. Conflict between federal and state decision-making, leading to lack of institutional accountability, is a problem throughout all stages of EIA implementation. A first step would be to ensure professional standards are followed for certification of private consultants who prepare EIA reports. Another improvement would be for the GOI, states, and private developers to embrace new protocols released by the International Hydropower Association (*19*). These standards could help identify problems early in the EIA process, include more stakeholder public participation, and better target national and state parties to be held accountable for implementation. EIA revision must include comprehensive cumulative impacts and river basin assessments. This would aid project evaluation and increase India's capacity to engage in transboundary river negotiations.

Third, resettlement regulation reform would improve India's management of dam development. A roadmap for using social assessment data in project decision-making needs to be prepared. Rules governing how public participation is integrated into resettlement processes need to be tightened (*20*). Resettlement compensation must be reformulated. Historically, the GOI has approached resettlement as a law-and-order issue, not as one about loss of homelands and cultural traditions. Although the scale of potential new downstream resettlement across India is sobering (*21*), there are no data publicly available on how many citizens face resettlement because of Himalayan hydro projects. Regulators need clear resettlement rules before projects multiply.

Transboundary Politics of Hydropower

Beyond specific project concerns, there are political reasons to strengthen India's energy planning, EIA, and resettlement laws. The two most important basins for hydropower development in the country, the Brahmaputra and the Indus, are transboundary rivers that begin on the Tibetan Plateau (China) and flow into Bangladesh and Pakistan, respectively. Every neighbor of India with undeveloped hydropower sites is building or planning to build multiple dams, totaling at minimum 129 projects (*22*). There has been little coordination between nations; India is not unique as it appears ready to expedite environmental review of hydropower projects on these rivers to gain "prior appropriation" of water resources before neighbors develop dams (*23*). Without negotiations to create integrated transboundary river basin planning, it is unlikely that any single nation's development can be optimized. This concern is underlined when projected climate change impacts on Indian Himalaya rivers are considered. Out to 2050 (well within the average lifetime of dams being built today), modeled decreases in mean upstream water supply from the Brahmaputra and Indus are 19.6 and 8.4%, respectively (*24*). Decreases of this magnitude may lead to reduction in a river's capacity to produce electricity, exacerbating regional political tensions over water-based energy production.

In this context, improved assessment of hydropower development in the Indian Himalaya assumes international significance. Given the large number of regional hydropower projects, it is essential to encourage transboundary river basin management throughout the Indian Himalaya and beyond (*25*). Multilateral energy partnerships between countries may eventually replace current state-focused development behavior. For India's proposed Himalaya dams, at minimum, it would be desirable to prioritize projects located in degraded forests, whereas construction around biodiversity-rich, dense forests and sites with thorny resettlement issues should be subject to integrated scientific and social review before final development decisions are made.

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