

Three-Gorges Dam—Experiment in Habitat Fragmentation?

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Biological species live in increasingly fragmented habitat islands embedded in a matrix of human civilization (1, 2). Although habitat fragmentation, including both the reduction in habitat area and the alteration of its spatial configuration, has been generally recognized as the primary cause of the loss of biodiversity and ecosystem services, its underlying processes and mechanisms remain poorly understood (3, 4). Our limited knowledge has come mainly from studies of terrestrial habitats that have been transformed by human activities (4, 5). Among the most enlightening studies of habitat fragmentation are a small number of large-scale field experiments, either unplanned like the islands in Gatun Lake of Panama and Lake Guri of Venezuela, both created by damming (6, 7), or planned such as the Biological Dynamics of Forest Fragments Project in central Amazonia (8, 9). Because planned experiments are usually prohibited by laws, moral scruples, and logistic and scientific obstacles, unplanned natural experiments are extremely valuable (10).

Large dams have created some spectacular modern-day land-bridge islands that can serve as natural ecological laboratories. By 2000, there were over 45,000 large dams in more than 150 countries, and each year 160 to 320 new ones are being built worldwide at the expense of wildlife habitat (11–14). The rapidly increasing geographic extent and high biodiversity of these altered ecosystems warrant substantial research efforts if global biodiversity and ecosystem services are to be sustained.

The world's largest dam, the Three-Gorges Dam (TGD), has been inserted in the middle of a biodiversity hot spot in south-central China. Labeled as the worst of the world's 20 most dangerous large dam projects (15), TGD is 2335 meters long and 185 meters high maximum (16). It is scheduled to start storing water and generating electric power in late 2003. The Three-Gorges Reservoir Area (TGRA) covers 58,000 km², an area 16,710 km² larger than Switzerland, and the reservoir

surface area will reach 1080 km² (16). Consequently, several dozen to more than 100 mountain tops may become modern land-bridge islands. We view TGD as an extraordinary opportunity for a grand-scale fragmentation experiment from which invaluable lessons can be learned.

Little affected by the quaternary glaciations, the TGRA is one of the richest areas in biodiversity in China (16–18), and the diversity of genera and families is among the highest globally. It is the home of 6388 species of higher plants, belonging to 238 families and 1508 genera and accounting for 20% of all seed plant species in China (16, 18). Fifty-seven of them are endangered plant species. TGRA also provides a diversity of habitats for hundreds of freshwater and



The location of the Three-Gorges Dam.

terrestrial animal species, many of which are rare or endangered. The extraordinary biodiversity of TGRA can also be seen at the ecosystem level. For example, Dalaoling Mountain, located at the north bank of the Xiling Gorge, displays a series of local ecosystems with distinct species compositions along the elevation gradient: evergreen broadleaf forests (below 800 m), evergreen and deciduous broadleaf mixed forests (between 800 and 1700 m), and deciduous and coniferous forests (above 1700 m) (17).

Undoubtedly, TGD will have significant impacts on biodiversity and ecosystem properties in this region. Some rare species have reportedly been endangered by the Gezhouba Dam (38 km downstream from TGD), constructed in the early 1980s, and the ongoing Three Gorges Project. These include the Chinese river dolphin (baiji), a living fossil of a 30-million-year-old species geo-

graphically unique to the Yangtze River (19).

The TGD will affect biodiversity and ecological processes in the area through both the immediate loss of habitat area and increased isolation of remaining habitat patches. The ecological impacts of TGD will become evident at several levels. For example, within each island, organisms and populations must adjust to the suddenly reduced area, more humid microclimate, and increased population density (which leads to increased predation and competition). The effects at the island community level will be reduced species diversity, reorganized food-web structure, modified nutrient cycles, and emerging features in the land-water zone. The biodiversity and ecosystem functioning of the area as a whole will continue to adjust to the newly created landscape configuration and regional context for decades. One particularly important aspect of this landscape change is the increased accessibility for humans to the mountain tops (by boat)—likely to lead to unprecedented tourism activities. To fully appreciate the ecological effects of the TGD, research and management policy must simultaneously consider the dual nature of fragmentation (habitat loss and isolation) and its multiple-scale and multidimensional effects.

Our initial survey of TGRA data suggests some exciting opportunities for developing and testing theories of island biogeography and habitat fragmentation. Supported by the Chinese Academy of Sciences and other government agencies, we and others are planning to measure ecological variables on these habitat islands, including species composition and diversity, population demography of dominant species, community trophic structure, plant growth rates, and ecosystem properties (e.g., soil water content, soil C and N, soil organic matter, litter decomposition, and biomass). As an immediate result of this work, it will be possible to measure extinction rates and determine if they vary with different taxonomic groups or trophic levels.

It will also be possible to determine if the species-area relation changes significantly over time. Faunal composition may change dramatically because animals are driven uphill by rising water, resulting in a short-term increase in species abundance, population density, and competition. Invasion of “foreign” animals and plants may not only alter species composition and trophic structure, but also drive some already endangered species to extinction, owing to increased predation and overgrazing. New riparian

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communities may develop near the interface between the “Three-Gorges Lake” and the remnant forests, which can significantly impact the island biotas and the regional landscape. In addition, changes in land-use patterns due to increased accessibility to mountain tops, in terms of tourism and resettlement of local people, may have various impacts on biodiversity. Aside from island biogeography, other perspectives of biodiversity and fragmentation, including neutral theory (20), metapopulation theory, self-organization of biotic communities, and landscape ecology (1, 21), should be considered.

Many hypotheses concerning fragmentation effects and biota relaxation require empirical data over decades or centuries (7, 8, 22), so it is critical to establish long-term monitoring programs with permanent field sites. Meanwhile, rapid biodiversity loss may occur immediately after “island” formation. For example, Barro Colorado Island, the largest island in Lake Gatun formed by damming the Chagres River in 1913, lost 45% of its breeding bird species in less than 50 years (7). The study of Terborgh *et al.* (6) in Lake Guri, created by damming in 1986, showed that small islands (<1 ha) lost 75% of their biological species within only 15 years, and that all islands lost their top predators within 4 years! A signif-

icant portion of the top predators in most small islands of TGRA may disappear at an even faster pace because of higher human population pressure. Thus, initial field surveys are essential to establish credible reference conditions for future research. This is especially true for species at higher trophic levels because they usually are much more sensitive to habitat fragmentation than those at lower trophic levels (6, 23).

One of the limitations with such natural experiments has been the lack of the baseline biological and land-use information before the habitat fragmentation. Such information has been inferred from often incomplete museum collections and historical records of the island biotas or their comparable mainland sources (23). Although the first detailed survey was a decade after isolation for Barro Colorado Island and 4 years later for Lake Guri, Chinese scientists have already begun to compile past and current ecological data for TGRA before the dam is fully operational (16–18).

The world’s largest dam is not only a demonstration of the mighty power of humanity; it can and should become a unique and rich source of information for understanding and conserving biodiversity and ecosystem services. To take advantage of this opportunity, international funding and long-term collaborations are needed.

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