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 significant 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.

References and Notes

1. J. Wu, O. L. Loucks, *Q. Rev. Biol.* **70**, 439 (1995).
2. S. Robinson, F. Thompson III, *Science* **267**, 1987 (1995).
3. G. R. Robinson *et al.*, *Science* **257**, 524 (1992).
4. Y. Haila, *Ecol. Appl.* **12**, 321 (2002).
5. J. Wu, J. L. Vankat, in *Encyclopedia of Environmental Biology* (Academic Press, San Diego, 1995), vol. 2, pp. 371–379.
6. J. Terborgh *et al.*, *Science* **294**, 1923 (2001).
7. J. Terborgh, *BioScience* **24**, 715 (1974).
8. W. F. Laurance *et al.*, *Conserv. Biol.* **16**, 605 (2002).
9. T. E. Lovejoy *et al.*, in *Conservation Biology: The Science of Scarcity and Diversity*, M. Soule, Ed. (Sinauer, Sunderland, MA, 1986), pp. 251–285.
10. J. M. Diamond, *Science* **294**, 1847 (2001).
11. The International Commission on Large Dams (ICOLD), established in 1928, defines large dams as those either higher than 15 m from the foundation, or between 5 and 15 m in height but with a reservoir volume of more than 3 million m^3.
12. World Commission on Dams, *Dams and Development: A New Framework for Decision-Making* (Earthscan, London, 2000).
13. M. Schrope, *Nature* **408**, 395 (2000).
14. W. F. Laurance *et al.*, *Science* **291**, 438 (2001).
15. R. L. Edmonds, *Global Ecol. Biogeogr. Lett.* **1**, 105 (1991).
16. Z. Huang, *Biodiv. Sci.* **9**, 472 (2001).
17. Z. Shen *et al.*, *J. Wuhan Bot. Res.* **18**, 99 (2000).
18. W. Xiao, J. Li, C. Yu, *Ecology of Terrestrial Plants and Animals in the Three Gorges Reservoir Area* (Southwest Normal Univ. Press, Chongqing, 2000).
19. X. Lei, *Science* **280**, 25 (1998).
20. S. P. Hubbell, *The Unified Neutral Theory of Biodiversity and Biogeography* (Princeton Univ. Press, Princeton, NJ, 2001).
21. J. Wu, *Landscape Ecology: Pattern, Process, Scale and Hierarchy* (Higher Education Press, Beijing, 2000).
22. J. M. Diamond, *Proc. Natl. Acad. Sci. U.S.A.* **69**, 3199 (1972).
23. G. A. B. Da Fonseca *et al.*, *Science* **295**, 1835 (2002).

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ECOLOGY

Protecting China's Biodiversity

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China is the most populous country, has one of the largest territories, has a booming economy (*1*), and recently has significantly changed its political leadership. As China's new top leaders begin to develop socioeconomic priorities, initiatives, regulations, policies, and legislation, it is important for them to expand the support for biodiversity conservation.

China has so many ecosystem types that it has >30,000 species of vascular plants [behind only Brazil and Colombia, (*2*)] and ~2340 species of terrestrial vertebrates (*3*), >10% of the world total in both cases (*2*). Perhaps half of China's species are found nowhere else; these include many archaic and distinctive evolutionary lines, like giant pandas and ginkgoes (*4*).

As elsewhere, China's biodiversity suffers from the explosive increase in the intensity and extent of human activities. Forest cover now accounts for only 16.5% of its area (*5*). Its rangelands are severely overgrazed, its wetlands are shrinking rapidly, and invasive species are an increasingly serious problem. Poaching of plants and wildlife is still common despite government bans. For example, tourist shops near some nature reserves conspicuously display skins of the endangered snow leopard. Air and water pollution are among the most severe in the world. The World Conservation Union (IUCN) 2002 Red List places China among the countries with the most threatened birds and mammals (*6*). Perhaps a quarter of its species are threatened (*7*).

To protect its biodiversity, China has established 1757 national and local nature reserves, most within the last 20 years (see figure, next page). They cover about 13% of the nation's area (*8*). Among them, 171 are national reserves (*9*), 21 have been designated Biosphere Reserves of the United Nation's Educational, Scientific and Cultural Organization's (UNESCO's) Man and the Biosphere Programme (*10*), and 7 have been designated globally significant wetlands (*11*). China has set an ambitious goal of increasing the number of reserves to 1800 (covering 15% of the area) by 2010 and 2500 by 2050 (*12*). These achievements are remarkable given China's population and the pressing need for economic development. Nonetheless, the nature reserve system faces serious challenges. We (*11*, *13*–*18*), together with others (*19*), have begun to address the major issues.

Enhance the National Plan and Administrative System

For the most part, lower-level government organizations have established national and provincial reserves, with ultimate approval by upper-echelon government organizations (*11*). This bottom-up approach rescued many threatened ecosystems and endan-

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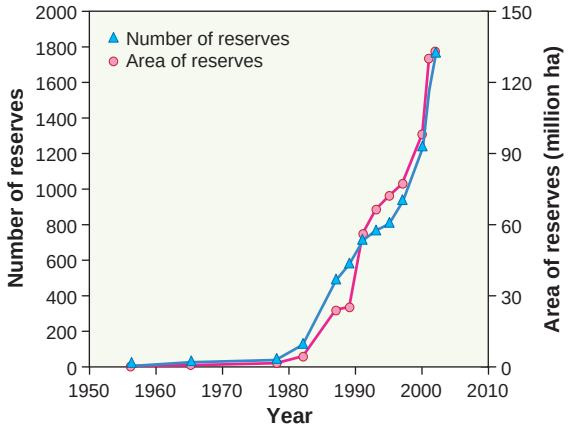
gered species from immediate loss, but it has been opportunistic. It lacks systematic planning and an adequate conceptual base. Most reserves are too small to ensure species survival and sustain ecosystem function. Many important areas are excluded. For example, no land managed by the military has been incorporated into the reserve system, even though some of it is ecologically diverse and contains many endangered and threatened species. In some countries (e.g., the United States), the military's primary mission still permits a secondary responsibility for stewardship (*20*). National reserve planning would identify priorities and gaps in the existing system, and the need for new reserves that could follow ecosystems across provincial and national boundaries. It might strengthen cooperation among reserves and regional bureaucracies.

National and local reserves are under the jurisdiction of several ministries and state agencies, including the State Forestry Administration (SFA) and State Environmental Protection Administration (SEPA) (*11*). Although most reserves are under the jurisdiction of SFA, SEPA is currently responsible for their coordination. Local governments manage most of the national reserves. The central government provides reserves only limited financial support; a third have no clear boundaries, no management teams, and no staff (*11*). The reserve system needs centralized management and coordination under the State Council. A new State Administration for Nature Reserves should be established with increased authority and funding, as well as a comprehensive Nature Reserve Law at the national level.



Growth of reserves in China.

Increase Investment

National reserves received only \$113/km^2 (operating and construction funds), much lower than the world average (\$893/km^2), and even lower than the average of reserves in developing countries (\$157/km^2). Local reserves receive only \$53/km^2 (*13*). Of 85 reserves surveyed, the government covered only about a third of their needs.

Economic activities of reserve staff (such as harvesting and selling resources unavailable to others) have caused severe damages (*14*), yet managers must pursue such practices to pay their staff. When local government assumes the management of national reserves, the central government should provide adequate funds (*11*). Similarly, locally owned and operated reserves should be accorded higher levels of attention by the pertinent governmental units (*21*). Based on carefully considered national priorities, additional funds should be sought from the private sector and from nongovernmental organizations and international organizations for the proper management of all reserves (*22*). A separate national budget should cover the operational expenses of national reserves, and local reserves deserve a separate budget from the local governments.

Tourism creates opportunities for employment and revenue (*23*), but it has also caused harm, including habitat destruction, landscape fragmentation, increases in pollution, and the introduction of exotic species (*23*). In the 11 high-profile reserves surveyed (*13*), visits increased from 942,000 in 1995 to 1,770,000 in 1998 (*13*). Tourism is being developed in the central regions of many reserves, which are often the most sensitive and biologically significant areas (*21*). Tourism must be managed to ensure long-term health and sustainability of the reserves, not short-term economic gain (*15*).

Help Local Communities

China's reserves are mostly in its poorer areas (*13*). Residents, neighbors, and local governments often view reserves as obstacles to human welfare and economic development. As elsewhere in the world, reserves will survive only if the residents' and neighbors' legitimate concerns are respected and addressed (*24*). Tourism and resource development should benefit local communities. Reserves should also help through technology transfer, such as replacing wood harvested for fuel with other, alternative-energy sources (*24, 25*). In the short-term, however, direct payments may be necessary to offset local communities' costs in forgoing extractive activities (*26*).

Conservation education has traditionally focused on increasing stakeholders' awareness to make them agree with and participate in conservation actions; it has not been very effective. There is another dimension of education that might prove much more cost effective. In the Wolong Nature Reserve, for example, the government has offered conservation education (and economic incentives) for residents to move out and thus to protect the giant pandas. Young people cause the greatest harm to the reserve, so encouraging their leaving will achieve the greatest benefit. This will not happen unless the quality of their education improves so that they can pass entrance exams to college or technical school. We recommend increased investment in schools (*17*, *18*).

References and Notes

1. World Bank, *World Development Indicators 2001* (World Bank, Washington, DC, 2001).
2. Compilation Group, *China's Biodiversity: A Country Study* (*in Chinese*) (China Environmental Science Press, Beijing, 1998).
3. Editing Group, Ed., *Action Plan for Biodiversity Conservation in China* (China Environmental Science Press, Beijing, 1994).
4. D. I. Axelrod, I. Al-Shehbaz, P. H. Raven, in *Proceedings of the First International Symposium on Floristic Characteristics and Diversity of East Asian Plants*, A. Zhang, S. Wu, Eds. (China Higher Education Press, Beijing, 1998), pp. 43–55.
5. Anonymous, *People's Republic of China National Report on Sustainable Development* (*in Chinese*) (China Environmental Science Press, Beijing, 2002).
6. IUCN, www.iucn.org/themes/ssc/redlist2002/rl_news.htm (2002).
7. P. H. Raven, in *Proceedings of the International Workshop on Science Frontiers and Priority Setting of NSFC Beijing, August, 1994*, Natural Science Foundation of China, Ed. (Peking Univ. Press, Beijing, 1994), pp. 137–152.
8. H. Guo, www.cenews.com.cn/english/2003-03-03/237.php (2003).
9. S. Zhao, www2.chinesenewsnet.com (21 May 2002).
10. G. Qu, www.wanweixinwen.com/gb/20011211/F0116.shtml (2001).
11. Z. Ouyang, in (*19*), pp. 22–34.
12. Anonymous, www.wildlife-plant.gov.cn/en/index.htm (2001). There are discrepancies between the various sources of data on how much land is in reserves. World Bank estimates the percentage at 6.4% for 1996, compared with 5.3%, the world average for countries with low to middle income (World Development Report 2001, Washington, DC). Chinese government data suggest that 7.13% of land was protected in 1995.
13. N. Han, in (*19*), pp. 1–21.
14. H. Miao, in (*19*), pp. 57–71.
15. X. Wang, in (*19*), pp. 81–91.
16. J. Liu, Z. Ouyang, Y. Tan, J. Yang, S. Zhou, *Popul. Environ.* **21**, 45 (1999).
17. J. Liu *et al.*, *Conserv. Biol.* **13**, 1360 (1999).
18. J. Liu *et al.*, *Science* **292**, 98 (2001).
19. China's National Committee on Man and Biosphere, *Study of Sustainable Management Policies for China's Nature Reserves* (*in Chinese*) (Scientific and Technical Documents Publishing House, Beijing, China, 2000).
20. V. H. Dale, D. T. Fortes, T. L. Ashwood, in *Integrating Landscape Ecology into Natural Resource Management*, J. Liu, W. W. Taylor, Eds. (Cambridge Univ. Press, Cambridge, UK, 2002), pp. 265–293.
21. H. Xu, in (*19*), pp. 72–80.
22. Most funds have come from the Chinese government, which has increased the budget. For instance, the State Forestry Administration contributed \$2.4 million to reserves in 2000 and \$29 million in 2002. International organizations have also contributed, but it is difficult to estimate their total support.
23. W. Li, in (*19*), pp. 92–109.
24. J. Liu *et al*, *Science* **293**, 603 (2001).
25. L. An *et al.*, *Ecol. Model.* **140**, 31 (2001).
26. P. J. Ferraro, A. Kiss, *Science* **298**, 1718 (2002).

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