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# CONTRIBUTIONS

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## *Commentary*

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### **Asian Ecology: Pressing Problems and Research Challenges**

#### **Introduction**

With more than a half of the world's population and an economic growth rate two to three times the global average, Asia is faced with a variety of ecological and environmental problems, including air pollution, water shortage and contamination, soil erosion, desertification, and resource depletion. Although the quality of life varies greatly among the nations, it tends to be correlated with the quality of the environment in general. With its huge human population and enormous biological resources, the ecological condition of Asia will continue to be crucial to the overall quality of the global environment. Many of the global ecological connections may be perceived in terms of biodiversity and biogeochemical cycles. In some cases, such global linkages are quite acute and spectacular. For example, the gigantic dust storm generated in northern China in April 2001 traveled over the Pacific Ocean to North America and then over the Atlantic Ocean, and a similar event reoccurred within less than a year, in March 2002!

It seems that now, more than at any time in the past, ecologists need to become more "global" in their research activities and perspectives because of the inevitably increasing global connectivity in ecology, economy,

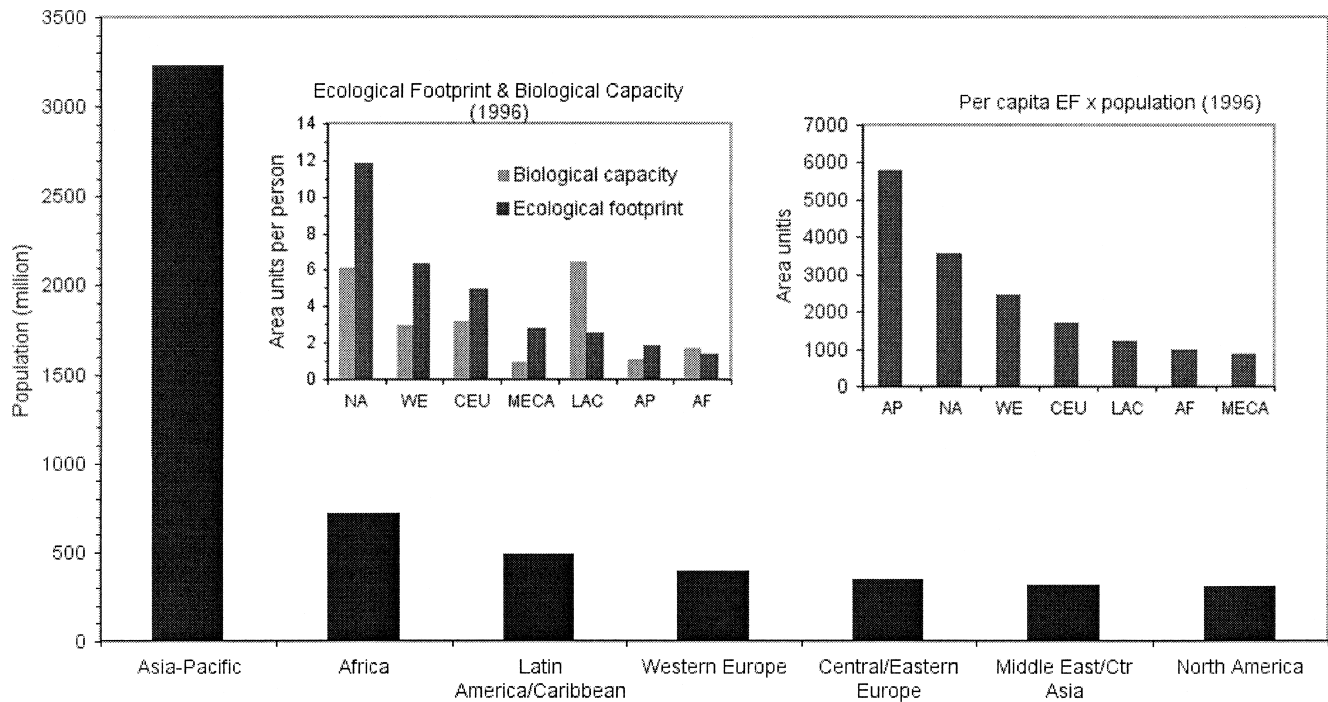
culture, and politics. Many ecological studies can benefit from a global perspective. This is especially true for human-dominated ecological systems where cultural and economic differences both contribute to and also constitute the solutions to the problems, and for broad-scale environmental problems that operate interactively in a global context. This paper provides a brief overview of some of the pressing environmental problems in Asia, as well as challenges and opportunities in ecological research.

#### **State of the environment: Living Planet Index and Ecological Footprint**

Two simple synoptic indices, the Living Planet Index (LPI) and the Ecological Footprint (EF), are helpful for acquiring an overall picture of general environmental conditions at regional and global scales. LPI is a measure of the natural wealth of the Earth's forest, freshwater, and oceanic/coastal ecosystems (WWF/UNEP 2000). LPI is calculated as the average of three indices that monitor population changes of animal species in forest, freshwater, and marine ecosystems, respectively. Each ecosystem index indicates the average population trend for a sample of animal species; its value at the reference year (1970) is set to zero. The forest index includes 319 species, the freshwater index includes 194 species, and the marine index includes 217 species (WWF/UNEP 2000). The three indices showed an average decline of about 12%, 50%, and 35%, respectively,

from 1970 to 1999, while LPI decreased by about 33% for the same period. The regional-level analysis suggests that LPI for Asia has declined faster than the global average (for more details, see Wu and Overton 2002).

The ecological footprint has been used to assess human pressures on the natural environment at spatial scales from individual humans, cities, and nations, to the entire globe (e.g., Wackernagel and Rees 1996, Folke and Jansson 1997, Luck et al. 2001). EF is usually calculated in terms of the area of biologically productive land or sea required to produce food, materials, and energy. In the case of energy, it also calculates the area needed to absorb the corresponding CO<sub>2</sub> emissions for a given population. The ecological footprint of an individual is the sum of six separate components: the area of cropland required to produce the crops consumed by that individual, the area of grazing land required to produce the animal products, the area of forest required to produce the wood and paper, the area of sea required to produce the marine fish and seafood, the area of land required to accommodate housing and infrastructure, and the area of forest that would be required to absorb the CO<sub>2</sub> emissions resulting from that individual's energy consumption. In 1996, the global average of the per capita ecological footprint was 2.85 ha of biologically productive space based on the world average productivity (i.e., EF area units); the footprint of an average consumer in the industrial-



**Fig. 1.** Population sizes of the different regions of the world and their ecological footprints (EF). EF is a measure of human pressures on the environment in terms of the area of biologically productive land or sea required to produce food, materials, and energy or to absorb CO<sub>2</sub> emissions for a given population (data from WWF/UNEP 2000).

ized world was about four times that in developing countries. The global ecological footprint has increased from about 9 billion area units in 1961 to 17 billion area units in 1997, and it increased by 50% between 1970 and 1997, a rise of about 1.5% per year (WWF/UNEP 2000). Although the per capita EF of Asia is relatively small in comparison to that of North America, its huge population size makes its regional-scale EF (per capita EF times the population of the region) much larger than that of North America (Fig. 1). The EFs of individual countries in Asia vary greatly, and have far exceeded the existing biological capacity in most countries (see Wu and Overton 2002).

### Some pressing environmental problems in Asia

*High population density.*—Asia has more than half of the nearly 6 billion world population. The problems of fast population growth and high population density are pervasive across Asia, and invariably are associated with the problem of the shortage of arable land (Wu and Overton 2002).

The average population density of the Asia-Pacific region reached 90 persons/km<sup>2</sup> in the early 1990s, while the average availability of arable land was only about 15% (FAO 1996, UNEP 2000). South Asia had the highest average population density (186 persons/km<sup>2</sup>), the highest percentage of arable land available (39%), and the lowest extent of forest cover (<20%). Southeast Asia, with a population density of 104 persons/km<sup>2</sup>, has more than 50% of its land forested and about 18% cultivated. East Asia's population density is 120 persons/km<sup>2</sup>, with only 9% of its area available as arable land. China may be the richest country in Asia in terms of absolute amounts of natural resources, but is among the poorest on a per capita basis. For example, the per capita arable land of China is only 0.086 ha, one-fourth the world average (0.344 ha); each Chinese has 0.133 ha of forested land, only 11.3% of the world average (JEC 2000). Rapid population growth in Asia has contributed to the destruction of natural habitats, widespread land conversion, and intensifying land use, resulting in ecosystem degradation, in-

cluding desertification, salinization and alkalization, land becoming waterlogged, and air and water pollution.

*Land degradation.*—Desertification has affected more than 100 countries across six continents; most of the desertified lands are found in Asia and Africa (Wu 2001). About 15 million acres (more than 6 million ha), an area equal to the state of West Virginia, become desertified annually. Of the world's rangelands, 73% are at least moderately desertified, and 47% of the world's rain-fed croplands are at least moderately desertified (Asia and Africa most seriously). Almost 30% of irrigated cropland is moderately desertified, of which Asia has the highest percentage. The Asia-Pacific region accounts for more than 70% of the world's agricultural population, but only 30% of the world's agricultural land. In many regions of Asia, the loss of vegetation cover and soil erosion due to water and wind are seriously altering the structure and function of natural ecosystems. In Asia, 16% of the agricultural land is considered severely degraded (loss of 50% of its production poten-

tial). In India alone, 38.5% of the 32.77 million ha of agricultural land have been affected by severe water erosion. China, with one-fifth of the world population, has more than 358,800 km<sup>2</sup> of desertified lands; over 96% of these areas (345,046 km<sup>2</sup>, including potential desertifying and desertified areas) are found in northern China (Zhu 1989, Wu and Loucks 1992). This large-scale land degradation in northwestern China may have been a major factor in the increasing frequency and scope of the horrifying dust storms in recent decades, which blacked out the city of Beijing and dimmed the sky of the western United States.

The two major types of land degradation in the Asia-Pacific region are water erosion (523.4 million ha, 61%) and wind erosion (238.6 million ha, 28%) (<UNEP www.eapap.unep.org>). Although both human activities and climate variations contribute to desertification, overcultivation, overgrazing, urbanization, fuelwood collection, and salinization are the primary causes. In the Asia-Pacific region, 310 million ha (37%) of land degradation was caused by vegetation removal, 280 million ha (33%) by overgrazing, 212 million ha (25%) by agricultural activities, 46 million ha (5%) by overexploitation, and 1 million ha (<1%) by industrial activities (UNEP/ISRIC 1990, Oldeman 1994, UNEP 2000).

*Urbanization.*—According to the United Nations, the world urban population was only a low percentage of the global population in the 1800s, but increased to nearly 30% in 1950 and 50% in 2000. Nearly 40% of the population of the Asia-Pacific region is urban, and the region is home to 13 of the 25 largest cities of the world. It has been estimated that by 2015, about 903 million people in Asia will live in cities with over one million people (WRI/UNEP/UNDP/WB 1998). Although the world urban population is projected to rise to 60% by 2025, nearly half of these people will reside in the Asia-Pacific region. Undoubtedly, urbanization in Asia will continue to have significant

impacts on the environment as well as on economic, social, and political processes at local, regional, and global scales (e.g., ESCAP 1993, Ness and Low 2000).

Rapid urbanization in most developing countries in Asia since the 1990s has been accompanied by a proliferation of slums and dysfunctional neighborhoods with high health risks. For example, it was reported that only 8 of the 3,119 towns and cities in India had full wastewater collection and treatment facilities, and 209 have partial treatment facilities (ESCAP 1993, UNEP 2000). High rates of urbanization and industrialization have increased the demands for land, water, and energy, and have resulted in expanding transportation networks that constitute a key accelerating factor in economic growth as well as environmental degradation. For example, urbanization and economic growth in many Asian countries frequently result in air and water pollution, loss of productive agricultural land, loss and fragmentation of species habitats, over-extraction of groundwater resources, and deforestation as a consequence of increased demand for construction timber (UNEP 2000). It is important to realize that the ecological influences of cities go far beyond the space that they occupy. Their ecological footprints can be enormous because of their huge demands for energy, food, and other resources, and the regional and global impacts of their wastes and emissions to soil, air, and water (UNEP 1999, Luck et al. 2001).

*Loss of biodiversity.*—It is estimated that 12.5 million species exist, of which 1.7 million have been identified (WCMC 1992). The moist tropical forests account for only 8% of the world's land surface, but probably hold more than 90% of the world's species. Asia is one of the richest regions in biodiversity, along with Africa, the Pacific, and Latin America (UNEP 1999). In particular, China, Indonesia, Thailand, India, Malaysia, and Papua New Guinea host a huge number of species of fish, amphibians, reptiles, birds, and

mammals, but unfortunately, Asia is also a region where biodiversity loss has been dramatic (for more details, see Wu and Overton 2002).

The underlying causes of the loss of biodiversity in Asia are mainly population growth, land use and land cover change, unsustainable exploitation of natural resources, the introduction of non-native species, international trade (particularly timber), and environmental pollution, including improper use of agrochemicals (UNEP 1999, 2000). For example, two-thirds of Asian wildlife habitats have been destroyed, with the most acute losses being in the Indian subcontinent, China, Vietnam, and Thailand (Braatz 1992). Air and water pollution stress ecosystems and reduce populations of sensitive species, especially in coastal zones and wetlands (UNEP 1999).

*Environmental pollution.*—Atmospheric pollution is a widespread problem in Asia (JEC 2000, Lelieveld et al. 2001). The Asia-Pacific region has experienced significant growth in atmospheric pollution due to the heavy use of coal and high-sulfur fuels, traffic growth, and forest fires (UNEP 1999). In West Asian regions, air pollution is only a problem in relatively large cities, but is exacerbated by the high temperatures and levels of sunlight. Although SO<sub>2</sub> emissions in Western, Central, and Eastern Europe fell by 50% between 1985 and 1994, in line with the Convention on Long-Range Transboundary Air Pollution protocols, they continue to increase in Asia and, in the future, will probably far exceed those in North America and Europe combined (see Wu and Overton 2002 for more details). The most serious air pollution problems often occur in urban areas. A survey by the World Health Organization (WHO) and the United Nations Environment Program found that the levels of suspended particulate matter (SPM) in 10 of the 11 cities that they examined were two times higher than WHO's guidelines: dangerous to human health. Problems of SO<sub>2</sub>, lead, and SPM pollution are serious in many cities of

the Asia–Pacific region (for more details, see Wu and Overton 2002). There is little doubt that air pollution will continue to increase in major Asian cities such as Beijing, Tokyo, Seoul, Taipei, Jakarta, and Bangkok in the early 21st century.

Other serious environmental problems in Asian cities include water pollution, solid waste accumulation and disposal (including toxic and hazardous wastes), and noise (UNEP 1999). Nonsource pollutions are a pervasive problem in most of the developing countries in Asia in which agriculture is the primary industry. For example, India alone uses 55,000 metric tons of pesticides per year, of which 25% end up in the sea, and increased use of pesticides has resulted in contamination of shell and finfish (UNEP 2000). The “red tides,” caused by blooms of particular plankton species, deplete oxygen levels, resulting in mass deaths of aquatic organisms, and have caused environmental problems in several coastal areas of the Philippines, China, and other Asian countries (UNEP 2000).

### **Challenges for ecological research**

Given the several pressing environmental problems, Asian ecology faces a number of grand challenges. Here, we discuss several major challenges that seem most urgent and important to Asian ecology in the coming decades. Some of these challenges, of course, are not unique to Asia, but are relevant to ecological research across the world.

#### *1) Crisis-oriented ecology as a research priority*

We use the term crisis-oriented ecology to refer to research that directly and rigorously tackles pressing environmental problems based on ecological theory, principles, and methodologies. In the history of ecology, many studies once were motivated primarily by the curiosity of the investigators, rather than real-world problems or societal needs. These “good old days” seem to have long passed.

While there are always a great number of intellectually or academically intriguing but realistically moot questions that ecologists can pursue, it is high time for us, as scientists and citizens, to assume the responsibility of helping to resolve real-world problems and improve the environment. Indeed, perhaps because of the exceptionally high population and already seriously deteriorated ecosystems in this region, Asian ecologists seem to be acutely aware of this, as seen by the emphasis of their research.

However, it remains a grand challenge to prioritize “crisis-oriented” ecological studies on the research agenda in many Asian countries because of: (1) the traditional perception that basic research is superior, (2) limited funding sources with many competing interests, and (3) attractions of internationally “trendy” or “political” research topics. In fact, the dichotomy between basic and applied ecological research may be misleading because the two are completely interdependent. Emphasizing crisis-oriented ecological research does not undermine the significance of more basic studies. Several fields may be considered crisis-oriented: conservation biology, restoration ecology, ecosystem management, ecological and environmental toxicology, agroecosystem ecology, and urban ecology.

#### *2) Integrating research with applications*

To effectively integrate research with applications, ecologists are challenged to deal with real-world problems, to work directly with resource managers, planners, and policy makers, to communicate across disciplinary boundaries, and to go beyond the “research–publication sequence” and promote the “research–application cycle.” Given the variety of political and economic conditions in Asia, such integration may take different forms and be carried out at different scales.

#### *3) Large-scale ecology*

Most environmental problems, such as biodiversity loss, land degrada-

tion, pollution, urbanization, and global climate change, must be dealt with on multiple and broad scales in time and space. Arguably, landscapes and regions based on biogeographical units and bioclimatic conditions may represent scales at which many of the pressing environmental problems can be tackled most effectively. Dealing with large-scale ecological phenomena requires theory, methods, and technologies (e.g., GIS and remote sensing) to acquire, analyze, and synthesize information on spatial heterogeneity of biodiversity and ecological processes across a range of scales. In particular, landscape and regional ecology, which are among the weakest areas in Asian ecology, ought to play a much more important role. In general, to achieve any long-term success in biodiversity conservation, ecological restoration, or environmental management, the landscape and regional context must be explicitly considered.

#### *4) Interdisciplinary and holistic ecological research*

Holistic research methods that emphasize the nonlinear interactions, emergent properties, and integrity of systems are quite familiar to many scientists in Asian countries (especially China and Korea). However, such approaches must go beyond the current more or less philosophical frameworks based on doctrines such as “yin-yang,” “five-element,” and “feng-shui,” and substantiate them with rigorous scientific methods. Also, interdisciplinarity is, or should be, a hallmark of crisis-oriented and large-scale ecology. To effectively study and resolve the pressing environmental problems in Asia, successful integration among different disciplines in earth sciences and between natural and social sciences is imperative. Such integration requires holistic approaches as well as collaboration among scientists, practitioners, and policy makers.

#### *5) Education and training*

Comprehensive and integrative university curricula and professional

training programs (within and outside academic institutions) need to be established and strengthened. These curricula and training programs should emphasize the interdisciplinarity and holistic nature of environmental and ecological problems. They also need to highlight the unique ecological and socioeconomic characteristics of Asian ecosystems, and accommodate the diverse needs of students and professionals who have different interests and backgrounds. In addition, through outreach programs and other means, effective communication with the public and decision makers needs to be an explicit part of the ecological program at both the university and national levels.

#### 6) *International collaborations*

International collaborations are critical for meeting any of these challenges in Asian ecology because: (1) The majority of the recent advances in ecological theory and applications have been made outside Asia. (2) As compared to the Western world, most Asian countries have a relatively small number of ecologists with respect to their huge population size, and they are often inadequately trained. (3) Many of the pressing environmental problems in Asia go beyond individual countries and even the continent. (4) Ecological research in most Asian nations, especially those developing countries, are seriously limited by funding sources.

There already exist several rather visible international collaborative networks that involve many countries and regions in Asia, such as MAB (Man and the Biosphere), ILTER (International Long-Term Ecological Research network), and GCTE (Global Climate and Terrestrial Ecosystems) of IGBP (International Geosphere and Biosphere Programme). Also, in recent decades an increasing number of international collaborative research projects have concentrated on the tropical and subtropical regions of Asia. However, more international collaborations at different levels and in different forms are needed, including ad hoc and periodic international

training programs and workshops for students and researchers, and collaborative research projects by individual investigators, institutions, nations, and international organizations.

With the increasing “globalization” of ecological problems and ecologists’ search for understanding and solutions, it is likely that more ecological scientists want to be engaged in international collaborations in Asia. We hope that this paper can be a stimulus for promoting further research collaborations between ecologists in Asia and the rest of the world. Finding potential collaborative institutions or researchers in some Asian countries can still be difficult, although the situation is improving thanks to the advances in information technology. We have compiled a number of research institutions in Asian countries (Wu and Overton 2002), with brief introductions and web addresses, that may be useful to those interested in ecological studies in Asia.

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