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Determination of priority nature conservation areas and human disturbances in the Yangtze River Basin, China

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ABSTRACT

Because of limitation of manpower, funding, and land available in conservation, the problem of how to select essential regions to establish protection systems for biodiversity maintenance has been widely discussed. In an effort to address the problem, this study has aimed to select a set of priority areas and to determine their priority order by quantifying human disturbances for each area in the Yangtze River Basin (YRB). This basin covers 2.143 million km^2, or more than 20% of China's territory. The habitats of 627 indicator species were predicted as a proxy for biodiversity. A conservation planning tool, MARXAN, was used to determine the optimal set of planning units, and three different target scenarios were generated. In addition, under the assumption that if two areas have equal value for conservation, the one suffering more severe disturbance needs more urgent protection than the other, priority ranking analysis was carried out using a 6-12-1 BP artificial neural network. Then hierarchical cluster analysis was applied to the classifications of human disturbances to formulate more detailed conservation strategies. By integrating the degree of irreplaceability of each unit, expert experience, and mountain boundaries, 17 biodiversity priority areas containing 33,200 units over an area of 0.83 million km^2 were defined. These areas also protected 56% of 32 types of rare forest ecosystem and 76.4% of six types of rare grassland ecosystem on average. According to the evaluation of human impact, a priority order and five types of human disturbance areas were generated. Some protection gaps were also identified, such as the northern part of the Wuyi Mountains. Moreover, the determination of priority nature conservation areas on a large scale can be used to influence the building of a well-connected protection network in each individual area, so that effective genetic communication can occur between species or groups of species. Conservation decisions focusing on the dominant impact factors that are threatening biodiversity sustainability are required as well.

Introduction

Biodiversity provides many products and services for humanity; however, in recent years, many species have become increasingly threatened by anthropogenic disturbances (Cardinale et al., 2012). To ensure long-term biodiversity maintenance, conservation actions must be urgently undertaken. These actions involve both *in situ* and *ex situ* conservation (Sarkar et al., 2002). In comparison with *ex situ* conservation, *in situ* conservation is more concerned with conservation in the conventional sense because it concentrates more on the preservation of intrinsic features and the long-term sustainability of biodiversity. A well-balanced *in situ* conservation system will protect biodiversity from the stresses of human activities (Bruinderink et al., 2003; Wu et al., 2011). Nevertheless, in the real world, funding limitations on land conservation initiatives lead to conflicts between economic development and conservation. This issue forces decision-makers to identify essential regions with low economic potential for conservation investment (Pressey et al., 2007).

Methods for selecting priority conservation areas generally include four aspects: mapping biodiversity richness using remote sensor data (Ranjeet et al., 2008; Rocchini et al., 2010); spatial clustering to identify planning units (Dunstan et al., 2012; Yu et al., 2005); eco-regional identification according to the distribution of rare ecosystems and ecosystem services (Egoh et al., 2007; Rogers et al., 2010); and site-selection algorithms (Lehtomäki & Moilanen, 2013; Possingham et al., 2000). Among these, site-selection algorithms have the unique advantage of being able to determine the mathematically optimal reserve system (Vanderkam et al., 2007).

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Using optimality as the core concept, systematic conservation planning combines many of the principles of conservation planning (e.g., total area, connectivity, spatial patterns, socioeconomic costs) to make explicit, effective, and accountable decisions that result in the reasonable allocation of scarce conservation resources (Margules & Pressey, 2000). Because of its advantage in the tradeoff between economic development and nature conservation, this approach is highly compatible with developing areas which are under increasing stress from human populations and land-use dynamics.

The Yangtze River Basin (YRB), the largest drainage basin in China, has experienced a booming economy over the last decade, and therefore human disturbances that negatively affect natural biodiversity have intensified. The YRB, as a globally crucial region for biodiversity conservation, contains a huge number of rare and indigenous species. More than 14,000 higher plants, 280 mammals, 762 birds, 145 amphibians, and 166 reptiles are represented in the YRB (Ouyang & Zhu, 2011). Meanwhile, settlements, roads, mineral-resource extraction, tourism, and many other types of human activity are widely and densely distributed across the basin, causing serious disturbances and threatening biodiversity within the region. Apparently, this has led to conflicts when selecting priority areas that are suitable for conservation status. In an attempt to address this problem in part, Heiner et al. (2011) identified a set of conservation areas for the protection of adequate biodiversity in the upper YRB based on the idea of systematic conservation planning, which represented important progress in conservation planning in this region. By contrast, this research presents the results of explicit conservation plans for the whole basin that focus mainly on terrestrial biodiversity and evaluate human disturbance independently to gather information that can be used to manage and improve conservation in this area, instead of being a component in the algorithm as a proxy of conservation cost.

The cost calculations associated with conservation are an important part of any systematic conservation plan. Cost estimation is a very positive and constructive contribution to the cost-benefit tradeoffs that occur during conservation planning. However, in many cases, it is difficult to quantify the economic costs of conservation, not only in monetary terms, but also according to other metrics (Banks & Skilleter, 2007). Therefore, a composite human-disturbance index has been developed by combining various factors, assuming that a planning unit with serious human impact incurs higher costs (Wilson et al., 2005). However, some regions with high conservation value are constantly managing the pressure of dealing with human needs, which forces them to be even more protective of their natural resources. Unless an alternative low-impact habitat is available, these areas are often developed because of their high associated economic potential. To avoid abandoning these high-value areas, threatening human factors should be considered separately rather than as a cost proxy. Some areas with intrinsic vulnerabilities demonstrate various levels of human impact where severe conflict exists between conservation initiatives and human activities. Once biodiversity has been destroyed, however, it is difficult to restore it to these regions due to their fragile nature and unique characteristics (Safont et al., 2012). In addition, analysis of human interference using site-selection algorithms enables decision-makers to make reasonable adjustments for resources, which makes a strong contribution to meeting conservation targets in priority areas. For this purpose, an ANN model was constructed to rank areas in terms of conservation priority, rather than merely by order of habitat irreplaceability. For example, if a unit has both high cost and high conservation values, an optimization procedure tends to abandon it due to fiscal concerns. However, these units require urgent investments that are separate from human pressures and have never been ignored. This is why human impact analysis was not included in the algorithm.

In this study, the first step was to identify indicator species and simulate their habitats to compile a dataset as a surrogate for biodiversity. The criteria for indicator species included the protection level and degree of endemic status according to several Red Lists. Maps of the predicted habitats were determined using several environmental variables that affect species habitat (e.g., altitude, vegetation type, slope, and aspect), which were obtained from the datasets of various historical research reports and field samples. Each variable was converted to a Boolean image that constrained the habitat to specific geographic regions. All these modeling results are required to use MARXAN (Marine Reserve Design using Spatially Explicit Annealing) (Game & Grantham, 2008), a site-selection algorithm developed to identify areas with high conservation value. Here, MARXAN was used to aid in the selection of suitable conservation sites in the YRB. After the sites were determined, human disturbance was estimated using an ANN model to quantify the characteristics and the degree of human impacts in each priority nature-conservation area.

The objectives of this research, therefore, were to obtain a solution for optimal-priority areas in the YRB and to analyze several target scenarios to obtain alternative conservation plans. In addition, quantitative analysis of the human impact in each priority area was performed by integrated estimation that considered several categories of existing threat factors, with the expectation that more specific conservation measures would be generated for priority areas.

Methods

Study area

The YRB and its neighboring regions include 829 counties, cities, and districts in 19 provinces. The total area of this watershed is approximately 1.8 million km^2, or 18.8% of China's territory. The river can be divided into three sections: (1) from the headwaters to Yichang, also known as the upper reaches (4504 km; 1 million km^2 drainage area); (2) Yichang to Hukou, or the middle reaches (955 km; 0.68 million km^2 drainage area); and (3) Hukou to the estuary, or the lower reaches (938 km; 0.12 million km^2 drainage area). After considering the integrity of the ecosystem and wildlife habitat, the research area was extended to include the Qiangtang Plateau, the Ruo'ergai marshes, the northern slope of the Qinling Mountains, Hunan Province, Jiangxi Province, and the Qiantang River basin in Zhejiang Province. The combined study area is 2.143 million km^2 in total (Fig. 1).

Indicator species

Species were required to meet at least one of the following selection criteria to be considered as indicators of biodiversity: (1) indigenous to China and endangered; (2) found mainly in China and endangered; (3) indigenous to China and under threat according to the *IUCN Red List of Threatened Species* (IUCN, 2004) and *First Volume of the Red Data List of Chinese Species* (Wang & Xie, 2004).

Species distributions were modeled using data included in species-location datasets or existing field studies, including (1) *China Animal Scientific Database* (CAS, 2011a); (2) *Scientific Database of China Plant Species* (CAS, 2011b); (3) *Chinese Biodiversity Information System* (CAS, 2005); and (4) *Chinese Species Information System* (CAS, 2001). The major types of vegetation, altitude, species, and other habitat data (e.g., aspect, slope) were determined from these databases and used in biodiversity richness mapping using the spatial analysis function of geographic information system (GIS) tools. All maps are presented in Boolean format.