A New Paradigm for Panda Research and Conservation

INTEGRATING ECOLOGY WITH HUMAN DEMOGRAPHICS, BEHAVIOR, AND SOCIOECONOMICS

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SINCE THE 1970S, many biological studies on giant pandas *(Ailuropoda melanoleuca)* have been conducted by scientists in China (e.g., Giant Panda Expedition 1974; Hu et al. 1980; Pan et al. 1988; Zhang et al. 1997) and from abroad (e.g., Schaller et al. 1985; Johnson et al. 1988; Reid et al. 1989; Reid and Hu 1991; Schaller 1993). These studies focused primarily on the biology of giant pandas in the field (including population dynamics, movement patterns, reproductive biology, and food habits) and in captivity (e.g., nutrition, reproduction, nursery for newborn pandas). For example, detailed individual information is available from those pandas that were captured, fitted with radio transmitters, and released (Schaller et al. 1985). However, as the main threat to pandas in the wild is the loss and fragmentation of their habitat (Chinese Ministry of Forestry and World Wildlife Fund 1989), biological studies alone are not sufficient for effective panda conservation. Future efforts to conserve wild pandas must focus on the underlying mechanisms influencing habitat loss and fragmentation, if effective policies are to be developed to maintain suitable habitat for viable populations.

Although some researchers have intuitively recognized that human activities are important factors causing the loss and fragmentation of panda habitat (Hu et al. 1980; Pan et al. 1988; Schaller 1993), no quantitative and systematic research had been undertaken to link panda habitats explicitly with human population and activities until a few years ago (e.g., Ouyang et al. 1995, 2000; Liu et al. 1999a,b; An et al. 2001; Liu et al. 2001a). Integrated analyses would have made many conservation policies and efforts more effective. For example, the Chinese government and some international organizations have tried to relocate residents living in Wolong Nature Reserve in Sichuan Province. Although some residents were relocated, many of them returned (Li et al. 1992; Liu et al. 2001a). Even relocation within the reserve was difficult to achieve. In the early 1980s, the Chinese government and the World Food Program built a large apartment complex in an area unsuitable for giant pandas within the reserve. The hope was to have local residents move voluntarily from the core habitat areas of Wolong to the apartment complex. However, not a single household did so. Liu et al. (1999a) found that in this instance, the elderly were accustomed to their lifestyle and did not want to relocate. Furthermore, there was insufficient land near the apartment complex for would-be migrants to farm. Because most of the local residents were farmers, they could not survive without land. These examples illustrate the need to understand the attitudes and needs of local residents before a conservation project is undertaken.

Integrated human–panda research is urgently needed to design and implement feasible policies. Studying the linkages between human dimensions and panda habitats requires a new paradigm that is different from traditional panda studies, encompassing not only ecological components but also major human dimensions (e.g., human demographics, behavior, socioeconomics) (Liu 2001). In this chapter, we provide an overview of this approach. We first introduce a conceptual framework, summarize some methods and results, and then describe some of our ongoing efforts. Finally, we discuss the perspectives of this new paradigm.

CONCEPTUAL FRAMEWORK OF THE NEW PARADIGM

Like many other wildlife species, the giant panda depends on forests for its habitat. Significant areas of forests in panda ranges have been altered due to human factors (Liu et al. 2001a,b). Human factors include demographic (e.g., population size and structure, household distribution), economic (e.g., income, expenses, production, consumption), social (e.g., needs and wants, perceptions and attitudes toward wildlife conservation), and behavioral (e.g., timber harvesting, fuelwood collection for cooking and heating). These factors are the primary forces influencing the rate and location of human impacts on forest systems and, consequently, affecting the spatial and temporal configuration of panda habitat (figure 14.1).

All three components (human, forest, and habitat systems) in the system framework can be directly or indirectly influenced by one another, and by external government policies and natural factors. For example, human activities are affected by other human factors, such as human needs. Human activities influence forests directly and panda habitat indirectly. Changes in forest structure, function, integrity, and dynamics can all have an impact on panda habitat quantity, quality, timing (when the habitat is available), and location. Government policies can significantly affect various aspects of the human system. However, the policymaking process and its effectiveness can also be shaped by the human system and panda habitat conditions. When panda habitat conditions are seriously deficient and human attitudes toward panda conservation are positive, government policies may be more favorable to panda conservation. Furthermore, the human system may be constrained by feedback from the forest system. For example, after all trees in a forest are harvested, local residents must adopt a different lifestyle without the use of timber and fuelwood. In addition, natural features of the physical environment (e.g., elevation, landslides) impact humans, forests, and panda habitats.

This conceptual framework guided our assessment of the impact of human factors on panda habitats in Wolong Nature Reserve. All components in the framework were incorporated into geographic information systems (GIS) as data layers and integrated into systems models as driving variables, state variables, or parameters. The integration, analysis, and modeling of these data helped us to answer many questions, such as:

1. How did panda habitats change before and after Wolong was established as a nature reserve?
2. How did ecological, socioeconomic, and demographic factors affect panda habitats?

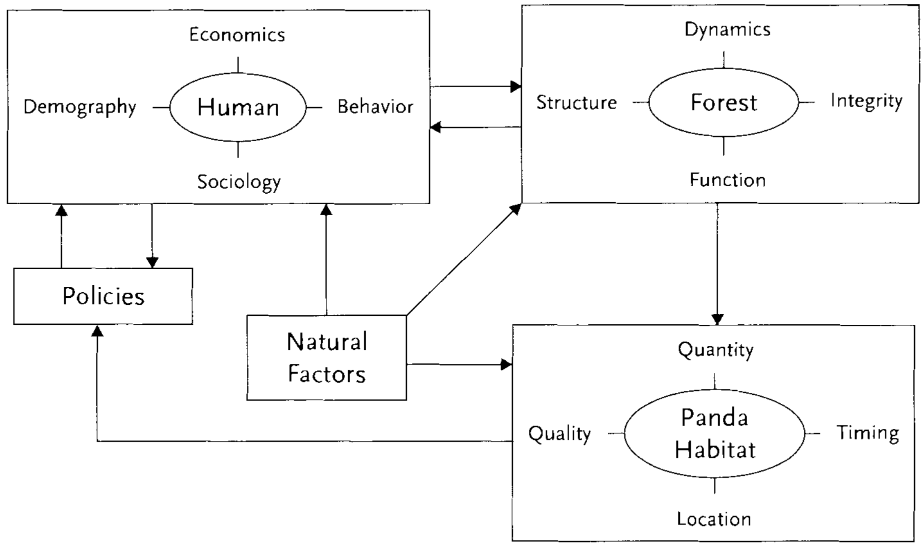

FIGURE 14.1. Framework of the new paradigm that integrates ecology with human demographics, behavior, and socioeconomics for panda research and conservation. Modified from Liu et al. (1999a).

3. How can various factors be modified to reduce human impacts on panda habitats?

METHODS FOR THE NEW PARADIGM

We chose Wolong Nature Reserve as our study site for four major reasons. First, it is one of the largest nature reserves (~200,000 ha) designated for conserving giant pandas and contains approximately 10% of the wild panda population (Zhang et al. 1997). Second, like many other nature reserves, there are local people residing in Wolong (more than 4,000 local residents in over 900 households in 1998). Third, Wolong is a "flagship" nature reserve and has received exceptional financial and technical support from the Chinese government and many international organizations since its creation in 1975. It is also part of the international "Man and Biosphere" reserve network (He et al. 1996). Fourth, many biological studies on giant pandas have been conducted in the reserve, and there is a good record of economic and demographic statistics. These previous studies and the data they produced provided a good foundation for our study.

Our new paradigm takes four general approaches: a systems approach, multiscale approach, interdisciplinary approach, and an integrated approach. The systems approach considers not only ecological factors, but also human demographic, behavioral, and socioeconomic factors; not only factors inside the reserve, but also those outside the reserve; not only what happened in the past and what is happening at present, but also what will happen in the future. The multiscale approach deals with issues at multiple spatial scales (e.g., patch, landscape), temporal scales (e.g., days, seasons, years, decades), and socioeconomic scales (e.g., individual, household, group [age, sex, educational levels], village, township, reserve). Our research team is interdisciplinary, consisting of researchers from such diverse fields as ecology, forestry, economics, sociology, geography, remote sensing, GIS, systems modeling and simulation, and reserve planning and management.

We used an integrated approach for data collection, data management, data analysis, data integration, and information dissemination. In terms of data collection, we combined field studies, interviews, government statistics and documents, information from the literature, and data from remote sensing (satellite and aerial photographs) and global positioning systems (GPS). The remotely sensed data included Corona photographs from 1965, LANDSAT Multispectral Scanner (MSS) data from 1974 (the year before the reserve was established), and LANDSAT Thematic Mapper data from 1997 (Liu et al. 2001a). The Corona data are stereo-pair photographs acquired on January 20, 1965, as part of the Corona photoreconnaissance satellite project (USGS Eros Data Center, Sioux Falls, South Dakota [Liu et al. 2001a]). Both LANDSAT MSS (January 3, 1974) and LANDSAT TM data (September 27, 1997) were obtained from China's Satellite Ground Station (Beijing, China). Four images of IKONOS data (different times between August 31 and November 16, 2000) with 1-m resolution were acquired through the National Aeronautics and Space Administration (NASA). The remote sensing data (Liu et al. 2001a) were georeferenced using highly accurate GPS receivers (Trimble Pathfinder). Field data were collected and georeferenced to the remotely sensed data using GPS locations to allow classifications of land covers, relate the spectral characteristics of the remotely sensed data to the spatial distribution of understory bamboo, and measure human influences and landscape structures. A Digital Elevation Model (DEM) was also developed from topographic maps and referenced to ground control points. GPS and satellite data were used to assist in gathering some socioeconomic data, such as household locations.

Ecological and geographical data included slope, aspect, elevation, vegetation community structure, plant composition, forest vertical structure, plant species richness, plant species diversity, bamboo biomass, bamboo density and species, forest canopy cover, mid-story cover, and understory cover (Ouyang et al. 2000; Linderman et al., in press). Data on the use of habitat by giant pandas (e.g., spatial distribution of panda feces) are also being collected (Bearer et al. 2000).

To understand the underlying mechanisms of habitat change, we have collected a large volume of social, economic, human demographic, and human behavioral data. Demographic data first became available in the 1960s, but in that decade and the next, the only available information concerned human population size. Three censuses (population censuses in 1982 and 2000 and an agriculture census in 1996) provided more detailed information (e.g., population structure, economic data). In addition, other demographic data (deaths, births, marriages, migrations) were available on an annual basis in most of the years in the 1980s and 1990s. Collection of social and behavioral data (e.g., perceptions, attitudes, activities) began in 1996. Economic data (e.g., income, expenses, production, consumption) have been available since the 1970s. We also surveyed local residents to identify economic activities of different age groups (Liu et al., unpubl. data) and investigate the amount of fuelwood consumption at the household level (An et al. 2001).

After the data were collected, they were entered into and managed using a relational database program (ACCESS) and GIS. Data were analyzed using spatial statistics, GIS, and statistical packages, such as SAS, S-Plus, and SPSS. Classification of remotely sensed data was initially accomplished through visual interpretation of a limited set of spectral data (to allow consistent analyses of different remote sensing images for a multitemporal study), unsupervised classification (for comparison analyses in a multitemporal study), and supervised classification using recent ground-truthing (for current landscape analyses).

Results from data analysis were then integrated into systems models using systems modeling and simulation techniques (Liu et al. 1999a), as well as decision support systems (DSS) (He et al. 2000). The model results are useful for decisionmakers in choosing desirable management alternatives to achieve both ecological and economic goals. We have developed systems models to link panda habitat data to socioeconomic and demographic data. In addition, we used computer simulations to project possible human demographic and ecological consequences of different policy scenarios (Liu et al. 1999a). For example, under different birth rates, emigration rates, emigrant composition (e.g., young versus old people), and levels of fuelwood consumption, we were able to project the future dynamics of human population sizes and structures, as well as panda habitats, over a period of fifty years (Liu et al. 1999a).

SOME RESULTS

Many results have been generated from our research (see, e.g., Liu et al. 1999a,b, 2001a,b; Ouyang et al. 2000; An et al. 2001; Linderman et al., in press). Here we present some of these results, including overall habitat changes within Wolong Nature Reserve, the influence of the human population and behaviors on the habitat, and how policy could potentially alter those behaviors for conservation purposes.

Both the quantity and quality of the panda habitat in the reserve continued to decline after the reserve was established (figure 14.2). More unexpectedly, rates of loss and fragmentation of high-quality habitat were higher after the reserve's establishment. The loss and fragmentation of panda habitats in Wolong were directly due to forest loss and fragmentation, as large tracts of forests were divided into smaller tracts and forest fragments were reduced in size.

Human population and behavior were the ultimate reasons for the much higher rates of loss and fragmentation of high-quality habitat after Wolong was designated as a nature reserve. As figure 14.3 shows, the number of local residents increased approximately 70% between 1975 and 1996, and the number of households more than doubled. The population structure has also changed dramatically (Liu et al. 1999b). For example, the number of children (0–19 years old) declined by almost 17% between 1982 and 1996, whereas the number of young adults (20–34 years old) almost doubled (~98%) during the same period. The main labor force (20–59 years old) increased about 60% from 1982 to 1996. Finally, the number of seniors (≥60 years) increased by almost 25%. The sex ratio (male:

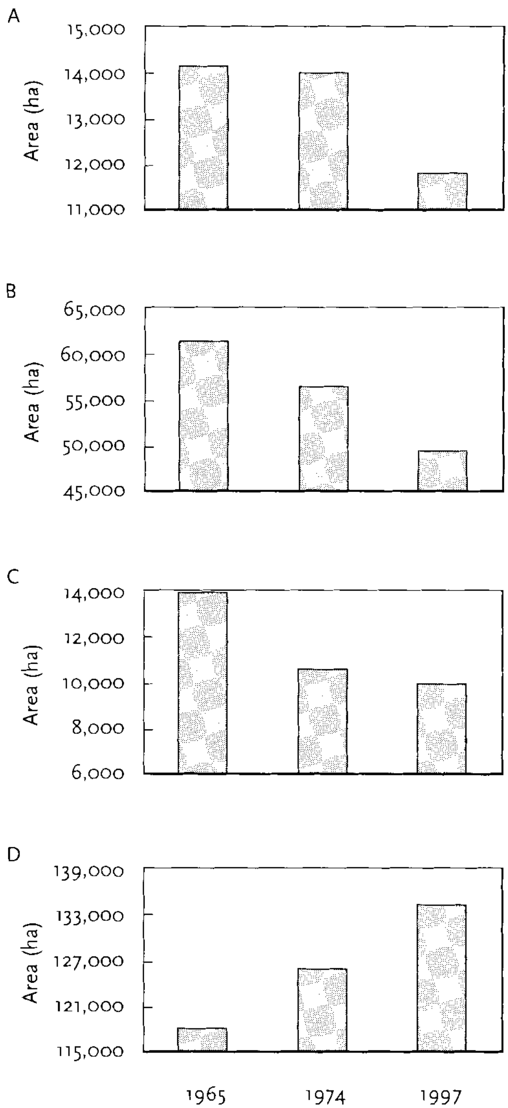

FIGURE 14.2. Change in the amount of panda habitat in Wolong Nature Reserve before and after the reserve was established in March 1975. (A) Highly suitable habitat; (B) suitable habitat; (C) marginally suitable habitat; (D) unsuitable habitat. From Liu et al. (2001a), with permission.

female) of young children (0–4 years of age) was 0.98:1 in 1982 but changed to 1.20:1 in 1996. In the age class of the oldest residents (>70 years), the sex ratio was 0.57:1 in 1982, but changed to 0.98:1 in 1996. More of the men lived longer in 1996 than in 1982.

The local resident population in Wolong will continue to increase, given the current birth rates, death rates, and migration rates (Liu et al.

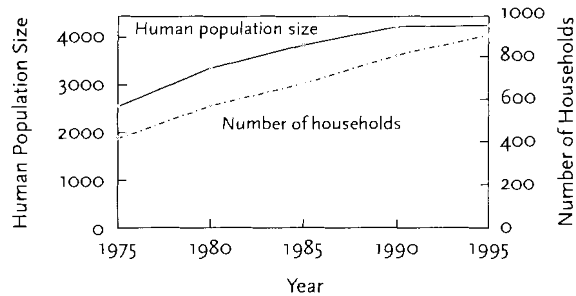

FIGURE 14.3. Human population and household dynamics in Wolong from 1975 to 1995. From Liu et al. (1999a), with permission.

1999a). Based on our projection (Liu et al. 1999a), the Wolong population will increase from 4320 in 1998 to 5960 in the year 2047. If the rate of emigration (all people in a household, both young and old) increases to 3%, the population will be reduced to 1671 by the year 2047. However, emigration of young people would be more effective in reducing human population size, because these emigrants would then not have children on the reserve, thus reducing the total number of potential residents and emigrants in the future. For example, relocating only 22% of the young people (17–25 years of age) would lead to a total population of 762 in the year 2047. Over a period of fifty years, the household emigration approach and the youth emigration approach would lead to a total of 4553 and 2189 local residents, respectively. Also, we found that, unlike the older residents in Wolong, the vast majority of young people were willing to move out of the reserve, especially if they were given the opportunity for higher education and jobs in the city. Furthermore, although senior residents themselves generally do not want to relocate, they are supportive of relocation by their children or grandchildren. In fact, they would feel very proud if their children or grandchildren could go to college. This shows that youth emigration would not only be more effective, but also more socially feasible.

Among various human activities, fuelwood consumption is the main factor affecting panda habitat at Wolong. Fuelwood is the major energy source for heating as well as cooking food for both humans and pigs (the main livestock in the reserve). Fuelwood consumption takes place at the household level and varies with household size, composition, economic status, and social attitudes. For example, a household with a senior resident (>60 years of age) consumed 19% more fuelwood for heating in the winter than a household without a senior (An et al. 2001). Households with a senior resident start the heating season earlier and end the heating season later in the year. An et al. (2001) developed a model to predict fuelwood consumption under different socioeconomic and demographic conditions. The model accurately estimated the actual amounts of fuelwood consumption. The amount of fuelwood consumption for heating had no significant relationship with household size, but the amount of fuelwood used in cooking was positively related to household size.

ONGOING WORK

In this chapter, we have highlighted several aspects of our ongoing work, including mapping the spatial distribution of bamboo, impacts of forest harvesting on giant panda habitat use, habitat restoration, and DSS. We are expanding this work, using the paradigm just described.

Bamboo is the staple food of pandas (see Long et al., chapter 6). The significance of bamboo distribution to panda populations has been well recognized (Reid et al. 1989; Reid and Hu 1991; Taylor and Qin 1997). However, because bamboo is an understory species mostly distributed in areas of complex topography, its distribution is difficult to map. To date, there is only cursory information gathered by ground surveys (but see Yong et al., chapter 10, and Liu et al., chapter 11). Although detailed maps exist for some small areas, large-scale maps, based on information from more general field surveys, are less useful. Remote sensing is a widely used method for large-scale data acquisition, but methods to map such understory species as bamboo, even including the use of aerial photography, have not been successful (Morain 1986; DeWulf et al. 1988; Porwall and Roy 1991). Combining field ground-truthing data with neural networks (an artificial intelligence technique), we were able to map the bamboo distribution for the entire Wolong Nature Reserve with an overall accuracy of 80% (Linderman et al., in press). The information for bamboo distribution is being incorporated into further habitat analysis (Linderman et al., unpubl. data). Furthermore, the method used in bamboo mapping will be very useful for mapping bamboo distribution in other parts of the panda's range and in studies of biodiversity, particularly understory vegetation and species that depend on understory vegetation as food or cover.

As noted in our review of results achieved to date, high-quality habitat for giant pandas has decreased markedly over the past several decades, due to human activities occurring within the original range of the giant panda. Of these activities, timber extraction and fuelwood collection greatly contributed to the reduction and fragmentation of their habitat. Thus, it is critical to ascertain how these harvesting activities have affected the use of habitats by giant pandas. Monitoring of panda activity (e.g., using feces and feeding sites as indicators) is being conducted in harvested and nonharvested areas throughout Wolong Nature Reserve. These data are being collected in a spatial format that will allow for comparisons with bamboo distribution and human demographic models, and will also provide necessary information for a landscape-level model of habitat use to be constructed. Preliminary results suggest that pandas avoid large, recently harvested areas (Bearer et al. 2000).

To effectively restore panda habitat in Wolong and other areas in Wenchuan County, Ouyang et al. (2001) began developing a landscape approach to China's national "return-steep-cropland-to-forest" program and "natural forest conservation" program. As the names indicate, these two programs have great potential for panda habitat restoration. Thus, we are creating integrated methods for evaluating the ecological and economic consequences of these two programs. Also, we are exploring integrated approaches to better plan and implement these programs in the Wolong-Wenchuan region for panda habitat restoration. Our new paradigm provides a good basis for such restoration efforts.

To better manage nature reserves for giant pandas (see Yu and Deng, panel report 13.1), we are developing a DSS (He et al. 2000) that integrates ecological, social, economic, behavioral, and demographic information. It provides a platform for conservation biologists, local residents, government officials, reserve managers, panda lovers, and perhaps other stakeholders to share their knowledge and concerns, evaluate long-term consequences of different policy scenarios, and make balanced and informed decisions about how to minimize the impact of humans on panda habitats. The DSS is web-based and integrated with spatial technologies, such as GIS, and dynamic systems modeling.

DISCUSSION

Our new paradigm lays a good foundation for understanding spatiotemporal patterns and mechanisms of panda habitat changes in Wolong and other reserves. It also provides an integrated framework to guide efforts for the conservation and restoration of panda habitat. Because the paradigm encompasses many disciplines, it addresses fundamental issues that no single discipline can address by itself. Thus, we advocate greater participation and collaboration from other disciplines in future endeavors that would facilitate panda research and conservation.

Our studies indicate that it is critical to explore the primary factors that cause habitat loss and fragmentation. Understanding the basis of these problems is an important first step toward the development and implementation of feasible and effective strategies for solutions. It is essential that scientists work with various stakeholders, especially government agencies and the local people, in their research. On the one hand, scientists have obligations to provide scientific information to government agencies, so that sound management decisions can be made. On the other hand, government agencies should encourage and support more interdisciplinary research that cuts across boundaries of the natural and social sciences.

The needs and perspectives of local people must be better appreciated. It is important to provide them with economic incentives to bring conservation efforts to fruition, because local residents are the main cause of habitat loss and fragmentation. If their needs for food and fuelwood are not adequately addressed, local residents will continue to cut down the forests that are home to the pandas. It is encouraging that Wolong Nature Reserve is implementing a natural forest conservation program that pays a household to take care of a specific forest area. Wolong has also built an "eco-hydropower" station designed to provide electricity to local residents for cooking and heating. Our research indicates that the price of electricity must be affordable and the supply of electricity must be stable for local residents to switch from fuelwood consumption to electric power (An et al. 2002). The natural forest conservation program and the eco-hydropower station program appear promising, but their effectiveness remains to be seen. Such long-term solutions as encouraging and helping more young people to move out of the reserve will reduce human pressures inside and around the reserve. Through a new partnership among scientists, policymakers, reserve managers, and local people, innovative and feasible conservation policies can be successfully developed and implemented, and habitats for endangered species like the giant panda can be effectively saved, efficiently restored, and sustainably managed.

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