Chapter 10
Long-Term Ecological Effects of Demographic and Socioeconomic Factors in Wolong Nature Reserve (China)

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10.1 Introduction

Human population has exerted enormous impacts on biodiversity, even in areas with "biodiversity hotspots" identified by Myers et al. (2000). For instance, the population density in 1995 and the population growth rate between 1995 and 2000 in biodiversity hotspots were substantially higher than world averages, suggesting a high risk of habitat degradation and species extinction (Cincotta et al. 2000). Many regression models have been built to establish correlated relationships between biodiversity and population (e.g., Forester and Machlis 1996; Brashares et al. 2001; Veech 2003; McKee et al. 2004). These models are important and necessary, but they use aggregate variables such as population size, density, and growth rate, which may mask the underlying mechanisms of biodiversity loss and could result in potentially misleading conclusions. For example, does a declining population growth reduce the impact on biodiversity? Although global population growth has been slowing down, household growth has been much faster than population growth (Liu et al. 2003). The continued reduction in household size (i.e., number of people in a household) has contributed substantially to the rapid increase in household numbers across the world, particularly in countries with biodiversity hotspots. Even in areas with a declining population size, there has nevertheless been a substantial increase in the number of households (Liu et al. 2003). More households require more land and construction materials and generate more waste. Furthermore, smaller households use energy and other resources less efficiently on a per capita basis (Liu et al. 2003). Thus, impacts on biodiversity may be increased despite a decline in population growth.

To uncover the mechanisms associated with human population that underlie biodiversity loss and provide valuable information for biodiversity conservation, it is crucial to go beyond regression analyses and examine how demographic (e.g., population processes and distribution) and socioeconomic factors affect biodiversity at the landscape level. As many effects may not surface over a short period of time, it is essential to conduct long-term studies. However, landscape level long-term studies are costly, and it is very difficult to conduct experiments on some types of subjects, such as people. Fortunately, systems modeling has become a useful tool

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to facilitate landscape-scale long-term simulation experiments (Liu and Taylor 2002). For this chapter, we applied a systems model we had developed (An et al. 2005) to study the long-term ecological effects of demographic and socioeconomic factors in Wolong Nature Reserve, southwestern China.

10.2 Profile of Wolong Nature Reserve

Wolong Nature Reserve (Fig. 10.1) is located in Sichuan Province, one of China's most populated provinces. Designated in 1975 with a total area of approximately 2,000 km^2 to conserve the endangered giant panda, it is characterized by a dramatically varying biophysical environment. With elevations ranging from approximately 1,200 m to over 6,200 m, it encompasses several climatic zones and contains over 6,000 plant, insect, and animal species. Among them, 60 are on the national protection list (Tan et al. 1995). For such reasons, Wolong and its adjacent regions were listed as one of the 25 global "biodiversity hotspots" defined in the late 1990s (Myers et al. 2000), and in Conservation International's more recently expanded set of 34 biodiversity hotspots. Roughly 60% of Wolong is situated within the Mountains of Southwest China Hotspot (Mittermeier et al. 2005). Wolong enjoys high domestic standing as a "flagship" reserve and receives considerable domestic and international financial and technical support (Liu et al. 2001).

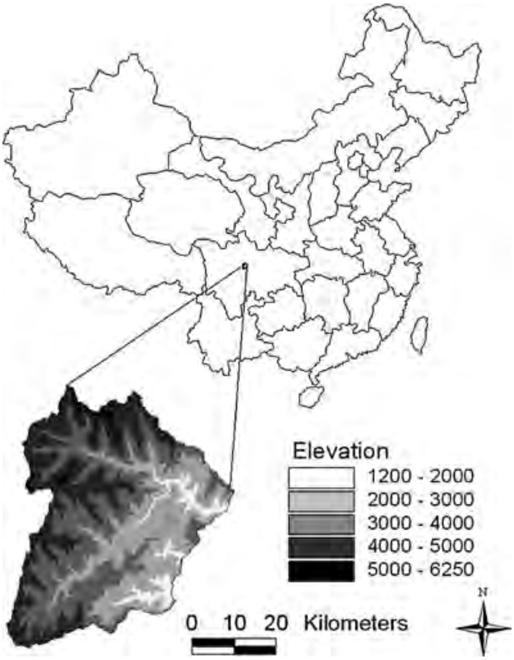

Fig. 10.1 The location and elevation of Wolong Nature Reserve in China (An et al. 2005)

In 2000, approximately 4,413 farmers lived in the reserve, mostly along the sides of the two main rivers running through the reserve; this population is made up of four ethnic groups: Han, Tibetan, Qiang, and Hui (Liu et al. 1999a). Local residents cut wood in the forests (on which pandas depend for habitat) for cooking and heating their households in winter, using electricity mainly for lighting and electronic appliances. Only a small portion of the households uses electricity for cooking and heating (An et al. 2001, 2002). No local market exists for fuelwood transaction, and the farmers collect fuelwood primarily in winter for their own use in the following year. Spending enormous amounts of time and energy for fuelwood collection, local residents find it increasingly difficult to collect fuelwood due to the shrinking forest area and topography characterized by high mountains and deep valleys. The reserve administration has implemented many policies to restrict fuelwood collection, including banning fuelwood collection in key habitat areas and prohibiting some tree species from being harvested. Enforcement of these fuelwood restriction policies tends to be ineffective because forests are a common property and difficult to monitor, given the rugged terrain. Even though electricity was available in the reserve, there was a continued increase in annual fuelwood consumption (from 4,000 to 10,000 m^3 from 1975 to 1999), contributing to a reduction of over 20,000 ha of panda habitat (Liu et al. 1999b). Degradation of forests and panda habitat was undoubtedly a factor in the reported decrease in panda population, i.e., from 145 individuals in 1974 (Schaller et al. 1985) to 72 in 1986 (China's Ministry of Forestry and World Wildlife Fund 1989).

The serious threat to the giant pandas comes from the subsistence needs of a fast growing population experiencing dramatic changes in age structure and other aspects. An even faster growth in household numbers may be contributing to the threat as well. Human population increased by 72.4% (from 2,560 in 1975 to 4,413 in 2000, an average 2.9% per year); but the number of households increased by 129.9% over the same period (from 421 to 968, an average of 5.2% per year; Fig. 10.2a).

The rapid increase in human population is due to a low mortality rate coupled with a higher fertility rate relative to other areas of China. Because of China's restrictions on migration through the household registration system (known as Hukou), along with Wolong's special standing as a nature reserve, the only legal way for people outside the reserve to migrate into the reserve is through marriage, and the number of such migrants is relatively low (An et al. 2001). For instance, 49 people (9 males and 40 females) migrated into Wolong through marriage over the period between 1996 and 2000 (An et al. 2005). The mortality rate has declined over decades in China (Fang 1993), and it is probable that Wolong has experienced the same trend (we do not have longitudinal data about mortality in Wolong). However, from the perspective of fertility, China's "one-child policy" has not been applied to minority ethnic groups such as Tibetans, which constitute over 75% of the total population in Wolong. This explains the relatively high total fertility rate (TFR) in Wolong, which was 2.5 in the 1990s (Liu et al. 1999a). Our field observations show that the fertility rate prior to 1990 likely exceeded 2.5, which contributed to the overall annual growth rate of 2.9% from 1975 to 2000,

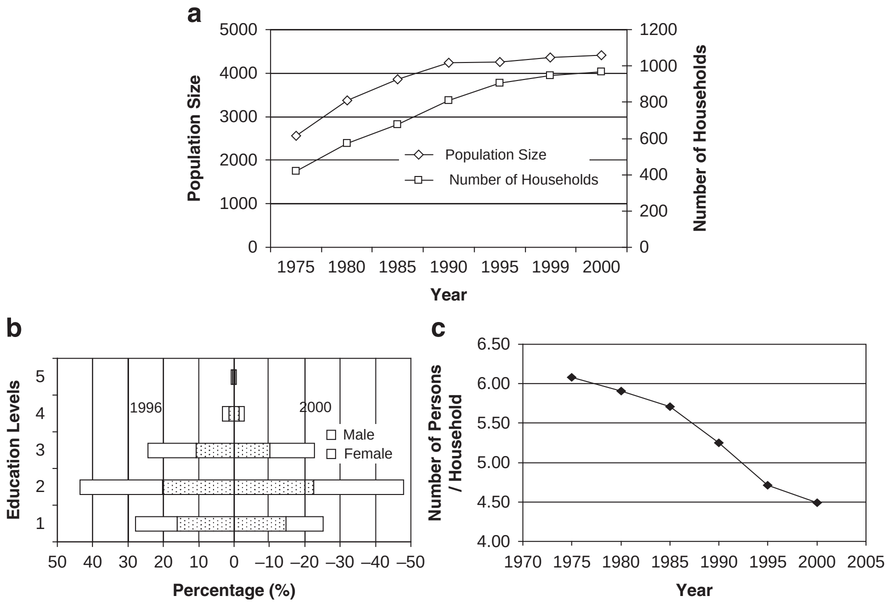

Fig. 10.2 Population of Wolong Nature Reserve. (**a**) The dynamics of population size and the number of households in Wolong between 1975 and 2000. (**b**) Education levels of Wolong population in 1996 and 2000, where level 1 is for illiteracy, 2 for elementary school, 3 for middle school, 4 for high school, and 5 for college, technical school, or higher. (**c**) Changes in household size from 1975 to 2000

together with other influences, such as a higher proportion of young people reaching the age of fertility during this period.

Previous research has shown that a change in the age structure could have a significant impact on biodiversity: the more young adults living in Wolong, the more forest may be cut down (Liu et al. 1999a). Average ages of local residents increased from 1982 to 1996, with a decreased portion of the people belonging to the 0–4, 5–9, and 10–14 age groups (Liu et al. 1999a; Wolong Nature Reserve 1997, 2000, Fig. 10.3). Changes between the 1996 and 2000 age structures were not as obvious as those between 1982 and 1996, probably because of the shorter time period. Overall, the groups that constitute the labor force (20–59 years) dominated the local population, consistent with China's general trend characterized by a decreased proportion of children (0–14 years) and an increased proportion of working-age (15–64 years) individuals (Hussain 2002). This decline was partly due to the "later, longer, and fewer" (wan xi shao) family planning campaign, encouraging or requiring couples to bear children later in life (later), prolonging the time between the births of two consecutive children if more than one child is allowed (longer), and having as few children as possible (fewer), which later developed into the more strict "one-child policy" in most parts of China, especially in cities (Feng and Hao 1992).

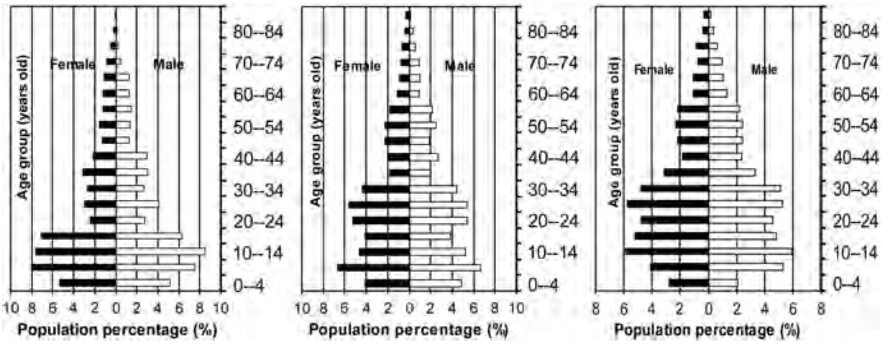

Fig. 10.3 Age and sex structures of Wolong population in 1982, 1996, and 2000

Young people's increasing preference for living independently may partially explain the faster increase in the number of households in Wolong. Traditionally, Chinese people were accustomed to a lifestyle of many generations under one roof (Liu et al. 2001); in rural areas of China, the patrilineal extended family is still the prevailing order, and the majority of the elderly people tend to live with their children (with sons in particular; Cooney and Shi 1999). Our research results, however, have shown that although young adults in Wolong care about the adverse effects associated with leaving their parental home (such as responsibility for housework and taking care of young children), many of them prefer to live independently as long as resources (land and timber in particular) allow them to do so (An et al. 2003). The proportions of larger households (6 or more people/household) declined from 1996 to 2000, while those with smaller households grew, with one exception: the proportion of households with three people declined slightly. Overall, the average household size declined from 6.08 in 1975 (Liu et al. unpublished data) to 4.60 in 1996 to 4.45 in 2000 (An et al. unpublished data) (Fig. 10.2c).

Temporary migration has become a hot topic in today's China, because seasonal workers in cities who maintain their permanent residence (characterized by the Hukou System) in rural areas have affected nearly all aspects of China's economy (Ma 1999). Wolong has seen a relatively lower proportion of such migration, probably for several reasons. First, its special standing as a nature reserve has provided subsidies (e.g., lower agricultural tax) for local people that are unavailable to those living elsewhere, and its local ecotourism centered on watching the panda in the breeding center has attracted some local people to work in local businesses such as hotels and restaurants. Our field observations have also shown that some young people work outside the reserve, returning only for holidays, such as the spring festival. As the gaps between Wolong and outside areas (Wolong vs. wealthier urban areas and Wolong vs. nearby poorer rural areas in terms of economic growth and job/education opportunities) widen, migration through marriages is expected to increase substantially. Therefore, we focus our concerns on migration through marriages, despite their relatively low numbers in the recent past.[1]

Females had lower education levels than males: in both 1996 and 2000, a higher proportion of females were at the illiterate level, and a lower proportion of females belonged to each of the other levels (Fig. 10.2b). This suggests that girls did not have the same chances for education as boys, probably due to the traditional patrilineal extended family structure. The gender difference in education may increase the probability that girls migrate out of Wolong through approaches other than education-migration (i.e., moving out of Wolong through going to college and finding jobs outside).

The pooled data (data for both females and males) show that the overall education situation improved over time: illiteracy declined from 31% in 1982 (Liu et al. 1999a) to 28% in 1996 and to 25% in 2000. This change may indicate that in the future, a higher proportion of children may pass the national college entrance examinations, go to college, and settle down in cities after finding jobs there, which could be a source of family pride for most of the parents in Wolong. According to Liu et al. (2001), the vast majority of middle-aged and elderly residents were not willing to move out of the reserve due to their low level of educational attainment (Fig. 10.2b), difficulties in finding jobs in cities, and/or difficulties in adapting to outside environment. However, they generally took pride in their children and grandchildren doing so.

All such demographic and socioeconomic factors may affect panda habitat to varying degrees, especially over a long time. Thus, it is very important to quantify the magnitudes of changes in panda habitat (an indicator for local biodiversity) caused by these factors. This chapter represents our attempt to examine the effects of demographic and socioeconomic variables on panda habitat in the Wolong Nature Reserve.

10.3 Long-Term Ecological Effects of Demographic and Socioeconomic Factors

We are interested in how changes in the demographic features (e.g., age structure, fertility) and socioeconomic conditions (electricity-related factors, particularly because of electricity's potential as a substitute for fuelwood) could affect panda habitat over a long time in a spatially explicit manner. Major questions of interest include (1) Which demographic and socioeconomic factors have significant (positive or negative) impacts on panda habitat? (2) How could economic factors, such as an electricity subsidy, conserve panda habitat? (3) How do spatiotemporal patterns of

[1]There were 49 (9 males and 40 females) people who migrated into and 67 (9 males and 58 females) people who migrated out of the reserve due to factors such as social networks established by seasonal workers.

panda habitat respond to changes in a combination of demographic and socioeconomic factors?

10.3.1 Design of Simulation Experiments

To answer the above questions, we designed a set of simulation experiments to understand how demographic and socioeconomic factors, when at play individually, would impact the two intermediate variables (population size and number of households), and our ultimate state variable (panda habitat), over space and time (Table 10.1). Through computer simulations, we tested a series of hypotheses (presented in Table 10.1) regarding the impacts of demographic and socioeconomic variables. First, for mortality and family planning factors, we examined the effects of mortality rates. We assumed that Wolong had been going through the same declining trend as the rest of China, reducing the mortality rates for all the six age groups by 50%. Second, we varied the fertility from 2.0 (average number of children allowed by the current policy in Wolong) to 1.0. This reduction is consistent with the fact that although Wolong currently has a higher fertility rate than cities in China, based on our field observations, many women in Wolong will tend to have fewer children in the future. Third, we examined the effects of birth interval by varying the length of birth interval (the time between the births of two consecutive siblings) from 3.5 to 8 years, corresponding to the "longer" part of the "fewer, longer, and later" family planning policy. Last, we examined the effects of marriage age by varying this age from 22 to 32 years old, corresponding to the "later" part of the policy.

To examine the effects of household formation and migration, we first evaluated the effects of "leaving parental home intention", the probability that a "parental-home dweller" (an adult child who remains in his/her parental household after marriage) would leave the parental household and set up a new household. We reduced the intention from 0.42 to 0.05, to encourage young adult children not to leave their parents' homes after marriage, which would probably result in larger household sizes and fewer households in the reserve. Second, we assessed the effects of education emigration – the migration of young people, aged 16–20 years, to college and other educational institutions outside the reserve (An et al. 2001). We used a variable "college rate" to indicate the proportion of children between 16 and 20 years old who could attend college. We varied the value of this variable from 1.92% to 50%, representing a policy alternative that could encourage more young people to move out of the reserve through approaches such as greater investment in education. This policy would be socially acceptable, due to the seniors' support of their children or grandchildren's outmigration to attend college (see Sect. 10.2). Last, we examined the effects of marriage migration, represented by a rise (from 0.28% to 50%) of "female marry-out rate", the ratio of the females between 22 and 30 years old who moved out of the reserve through marriage to all the females in this age group at a given year (An et al. 2005).

Table 10.1 Design of simulation experiments

Type of factors	Variable	Hypothetical impact[a]	Value of status quo	Individual experiment	Combined experiment	
				Changed value	Value for conservation scenario	Value for development scenario
Mortality and family planning factors	Mortality	+	Age dependent[b]	50% decrease		
	Fertility	–	2.0	1.0	1.0	4
	Birth interval	+	3.5	8.0	8.0	1.5
	Marriage age	+	22	32	32	22
Population movement factors	Leaving parental home intention	–	0.42	0.05	0.05	0.84
	College rate	+	1.92%	50%	50%	0.0%
	Female marry-out rate	+	0.28%	50%	50%	0.0%
Economic factors	Electricity Price	–	Location dependent	0.05 Yuan decline	0.05 Yuan decline	0.05 Yuan increase
	Outage levels	–	Location dependent	One level decrease	One level decrease	One level increase
	Voltage levels	+	Location dependent	One level increase	One level increase	One level decrease

[a] Hypothesized impact of a demographic or socioeconomic variable on the amount of panda habitat. A "+" sign means that a change in the value of a variable will change the amount of panda habitat in the same direction (e.g., a decrease in mortality will result in a reduction on panda habitat), whereas a "–" sign means a change in the opposite direction (a decrease in fertility will give rise to an increase in panda habitat)

[b] See An et al. (2005) for details

To assess long-term effects of economic factors, we reduced the cost of electricity by 0.05 Yuan kw^{-1} h^{-1} (US $1 = 8.2 Yuan), reduced electricity outage by one level,[2] and increased voltage level by one level. These changes reflect the government's objectives of providing more high-quality electricity at a lower cost to substitute for the use of fuelwood. An "eco-hydropower plant" was recently constructed to achieve these objectives (M. Liu personal communication).

To understand the combined effects of various factors on population size, household numbers, and panda habitat, we designed a second set of simulation experiments with two opposing scenarios. The "Conservation Scenario" combined all the changes used in the above individual simulations that would help panda habitat conservation through decreases in human population, number of households, and fuelwood consumption. The "Development Scenario" set the values of all the related variables in the opposite direction (see Table 10.1), which would stimulate development of local economy and growth of local population and households. We chose a simulation period of 20 years for the economic factors, while we allowed demographic factors 30 years to take effect.

10.3.2 Model Description

To conduct the experiments outlined above, we used the Integrative Model for Simulating Household and Ecosystem Dynamics (IMSHED; An et al. 2005), which integrates various subsystems into a dynamic system that considers their interrelationships and the underlying mechanisms of various interactions from a systems perspective. IMSHED employs agent-based modeling (ABM) and geographic information systems (GIS). ABM can help predict or explain emergent higher-level phenomena by tracking the actions of multiple low-level "agents" that constitute or at least impact the system behavior observed at higher levels. Agents usually have some degree of self-awareness, intelligence, autonomous behavior, and knowledge of the environment and other agents as well; they can adjust their own actions in response to the changes in the environment and other agents (Lim et al. 2002). The model structure is illustrated in Fig. 10.4. IMSHED views individual persons and households as discrete agents and land pixels as objects. The layer of dashed households in the dashed box represents households at an earlier time, while the layer of solid ones represents households at a later time.

[2]Electrical outages had three levels: high, moderate, and low, representing more than 5, 2–4, and less than 2 outages per month, respectively. Voltage also had three levels, representing 220 V, 150–220 V, and fewer than 150 V (An et al. 2002). The default levels of outage and voltage for each household in the model were based on real data: values for a given household could be any of the three levels. If a specific household already has a low outage level, it would remain at that level regardless of the request of reducing outage level. Households with moderate or high levels of outage would have one level of reduction, resulting in low or moderate levels of outage, respectively.

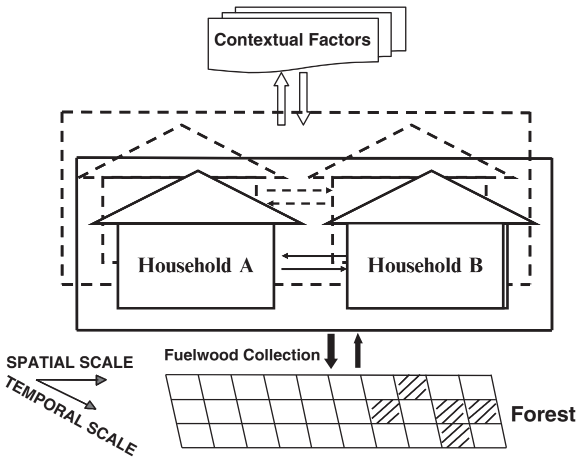

Fig. 10.4 Conceptual framework of the integrative model for simulating household and ecosystem dynamics (IMSHED; From An et al. 2005). Households A and B represent the households in Wolong, those within the *bold lines* refer to households at an earlier time and those within the *dashed lines* refer to households at a later time. The pixels at the *bottom* constitute the landscape of Wolong, where the *blank ones* are nonforest pixels and the *shaded ones* are forest pixels. Contextual factors include policy and geographical factors. The *arrows* stand for interactions between human population and the environment

The existing households (represented by households A and B in Fig. 10.4) come from the past and evolve into the future. They may increase or decrease in size, dissolve, or relocate. New households may be initiated as individual persons go through their life history. Household-level dynamics reflect individual-level events, such as birth, death, education emigration, and marriage migration.

A set of psychosocial factors determines or influences new household formation (An et al. 2003). Fuelwood demand is determined by a number of socioeconomic and demographic factors such as household size and cropland area (An et al. 2001, 2002). In the model, the forested landscape is divided into grid cells (pixels) to use the remotely sensed data and to facilitate simulations. In the process of fuelwood collection, a household evaluates the biophysical conditions (e.g., available forests and their topography), goes to an available pixel with the lowest perceived cost, and cuts trees for fuelwood. As a result, the forest pixel will be deforested and a nearby forest pixel will be chosen as the fuelwood collection site in the future. This process is part of the interaction between humans and the environment, as shown by the two arrows in Fig. 10.4. Initial conditions regarding tree species, growth rate, and total wood volume in each pixel are contained in the model. Contextual factors, including policies and geographical factors (e.g., elevation), also exert impacts on processes, such as household formation and fuelwood collection, and may ultimately impact panda habitat.

We used the data from 1996 to initialize all simulations. Although the total length of simulations ranged from 20 to 30 years depending on the objectives, the simulation time step was always 1 year. The model contains many stochastic processes, e.g., whether a person of a certain age group would survive a particular year depends on the number generated by the random number generator: if it is less than the associated yearly mortality rate, the person dies; otherwise he/she survives and moves to the next year. We ran a simulation 30 times (or replicates) to capture the variations among different replicates. We tested for the differences among various simulation results using two-sample *t* tests at the 0.05 significance level.

10.3.3 Simulation Results

Mortality and family planning factors affected population size, the number of households, and the area of panda habitat differently over a period of 30 years (Table 10.2). Compared to the baseline, population size significantly increased with a reduction in mortality (see Table 10.1 for their values in different simulations; the same for other variables hereafter) and decreased with a decline in fertility, a rise in birth interval, and an increase in marriage age (Fig. 10.5a). The number of households increased with the reduction in mortality, decreased with the decline in fertility and increase in marriage age, and remained nearly unchanged with the rise in birth interval ($p = 0.19$; also see Fig. 10.5a). With regard to panda habitat, the influences varied. All changes except the reduction in mortality ($p = 0.39$) significantly increased the amount of panda habitat (Fig. 10.6a).

Population movement (including migration and leaving parental home after marriage) factors affected population size, number of households, and panda habitat over 30 years significantly, with one exception (see Table 10.2). As expected,

Table 10.2 *T*-test ($\alpha = 0.05$) results in relation to the baseline situation[a]

Type of Factors	Variable	*t*-Statistic value (*p* value)		
		Population size	Number of households	Panda habitat
Mortality and family planning factors	Mortality	−34.32[b] (0.00)	−14.45 (0.00)	0.86 (0.39)
	Fertility	65.85 (0.00)	6.72 (0.00)	−2.52 (0.01)
	Birth interval	17.63 (0.00)	1.34 (0.19)	−2.04 (0.05)
	Marriage age	52.50 (0.00)	24.48 (0.00)	−13.70 (0.00)
Population movement factors	Leaving parental home intention	1.80 (0.08)	89.79 (0.00)	−22.81 (0.00)
	College rate	296.89 (0.00)	106.22 (0.00)	−25.73 (0.04)
	Female marry-out rate	95.76 (0.00)	38.48 (0.00)	−10.99 (0.09)
Economic factors	Electricity price	−1.31 (0.20)	−0.82 (0.43)	−46.70 (0.00)
	Voltage levels	0.79 (0.43)	−1.33 (0.194)	0.74 (0.46)
	Outage levels	0.13 (0.90)	0.40 (0.69)	−28.09 (0.00)

[a]Simulation lengths were 30 years for mortality and family planning as well as population movement factors, and 20 years for economic factors

[b]The "–" sign represents a reduction in value in the scenario compared to the associated value in the status quo, while no sign refers to an increase

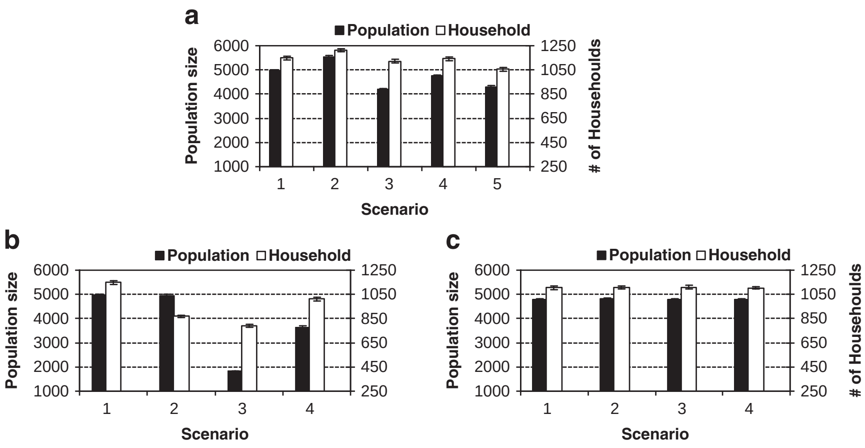

Fig. 10.5 Population size and the number of households in year 2026 (2016 for Economic factors) in response to changes in demographic and economic factors. (**a**) Family planning factors: scenario 1 for status quo, 2 for 50% reduction in mortality, 3 for fertility from 2.0 to 1.5, 4 for birth interval from 3.5 to 5.5, and 5 for marriage age from 22 to 28. (**b**) Population movement factors: scenario 1 for status quo, 2 for the intention of leaving-home from 0.42 to 0.21, 3 for college rate from 1.92% to 5%, and 4 for female marry-out rate from 0.28% to 20%. (**c**) Economic factors: scenario 1 for status quo, 2 for price reduction of 0.05 Yuan, 3 for one-level voltage increase, and 4 for one- level outage decrease. An *error bar* indicates one standard error

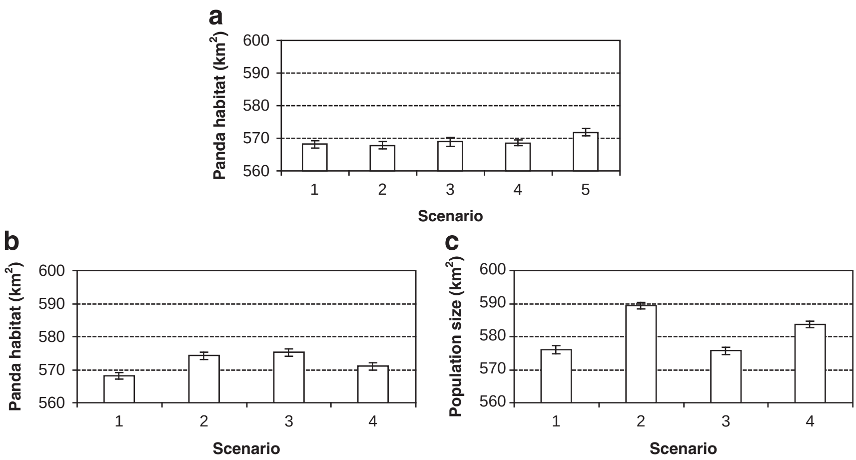

Fig. 10.6 Amount of panda habitat in year 2026 (2016 for Economic factors) in response to demographic and socioeconomic factors. (**a**) Family planning factors, (**b**) Population movement factors, and (**c**) Economic factors. The scenario definitions are identical to those in Fig. 10.5. An *error bar* indicates one standard error

the changes in the values of three population movement factors (a decrease in leaving parental home intention, an increase in rate of college attendance, and an increase in female marry-out rate) significantly reduced the number of households (see Fig. 10.5b). Their influence on population size varied, however. Leaving parental home had no statistically significant impact on population size ($p = 0.08$), while an increase in rate of college attendance and female marry-out rate significantly reduced population size ($p < 0.01$). The amount of panda habitat increased significantly (except for female marry-out rate with $p = 0.09$) as a result of increases in the values of all three factors (Fig. 10.6b).

The economic factors considered in our model had varying effects over a period of 20 years (see Table 10.2). The three scenarios (a decrease in electricity price, an increase in voltage level, and a decrease in the outage level) (see Fig. 10.5c) had insignificant influences on population size. Similarly, their impact on the number of households was insignificant. However, changes in the value of electricity price and outage level increased panda habitat significantly, while a change in the voltage level did not change the panda habitat significantly ($p = 0.46$; also see Fig. 10.6c).

A comparison between the Conservation Scenario and Development Scenario showed that substantial gaps existed between their projected impact on population size, number of households, and panda habitat area, which were significant and widened over time (Fig. 10.7a–c). At the end of 2026, there would be 5,300 fewer people, 1,000 fewer households, and 53 km^2 more panda habitat under the

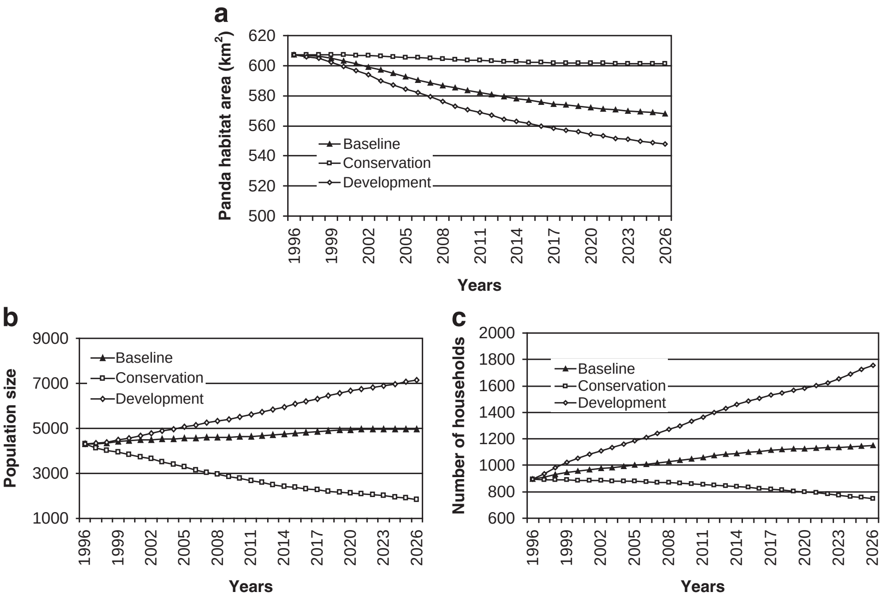

Fig. 10.7 (**a**) Panda habitat, (**b**) population size, and (**c**) the number of households under the status quo, conservation scenario, and development scenario over 30 years (1996–2026)

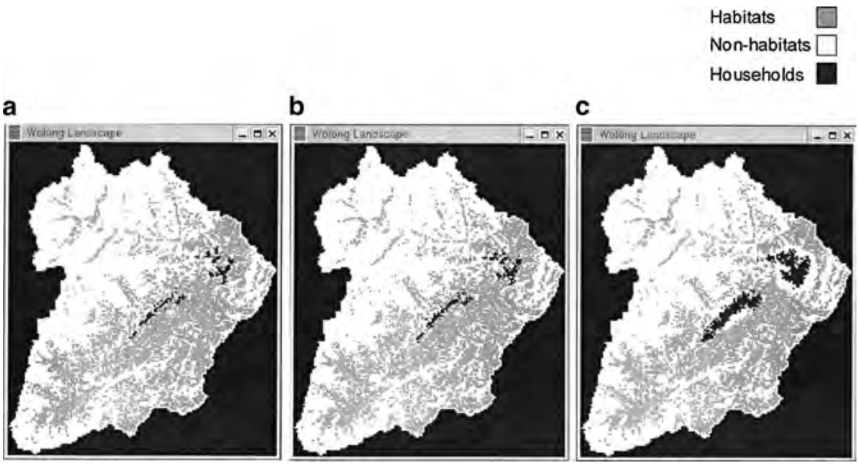

Fig. 10.8 Spatial distributions of panda habitat and households in 1996 and 2026 (desirable scenario, undesirable scenario) (An et al. 2005)

Conservation scenario than under the Development Scenario. When the spatial distributions of panda habitats and households were considered in the simulations (Fig. 10.8a–c), the impact caused by the demographic and socioeconomic factors became more apparent. For instance, much more panda habitat would be saved under the Conservation Scenario (Fig. 10.8b) compared to the Development Scenario (Fig. 10.8c), and the saved areas were located mainly near the households.

10.4 Discussion

According to our simulation results, mortality and family planning factors had a significant impact on population size, but a significant or insignificant impact on household dynamics and panda habitat. A change in mortality may take time to be translated into changes in population size and the number of households and ultimately into changes in panda habitat. The decline in fertility, the extension of birth interval between consecutive children, and delay in marriage age could reduce the number of new births, prolong the time between additional babies, and delay the birth of first babies (also increase the time between two generations), ultimately reducing demand for fuelwood, which may explain their significant effects in saving panda habitat. Although the magnitude (approximately 13.7 km^2 less habitat caused by an increase in marriage age) may be insubstantial compared to the total habitat area of 607.2 km^2 in 1996, it would make a greater difference when habitat distribution is considered. This study does not consider spatial factors, such as habitat fragmentation and the home range of pandas (2 km^2, according to Schaller et al. 1985). In our model, fragmented habitat (smaller than 2 km^2) has not been taken out. Thus, if a habitat of 100 km^2, for instance, were divided into small fragments of less than 2 km^2 each, the real loss would be 100 km^2 rather than zero.

Factors influencing population movement affected nearly all three response variables: population size, household numbers, and panda habitat. There were two exceptions: leaving-home intention and female marry-out rate showed no statistically significant effect on population size and panda habitat at the 0.05 significance level. Leaving-home intention largely deals with how likely it would be for a newly married couple to establish their own household, and it is not directly linked to population size. The female marry-out rate may need more time (i.e., longer than 30 years) to affect population size, household numbers, and, ultimately, panda habitat.

Economic factors had a significant impact on panda habitat because they encourage local residents to reduce their consumption of fuelwood by using more electricity. The Conservation Scenario and Development Scenario shed light on how demographic factors (especially those linked to population structure) and socioeconomic factors may influence panda habitat over time, illustrating substantial temporal and spatial differences in response to two opposite combinations of variables.

The results from our simulation study have important implications for the development of feasible and effective conservation policies. For example, promoting outmigration of young people through college education is not only socially desirable (Liu et al. 1999b), but also ecologically effective. Providing cheaper, more reliable, and higher-quality electricity for local residents could help them switch from fuelwood consumption to electricity use. A lesser dependence on fuelwood could help protect and restore panda habitat.

Future research should be directed towards the following aspects. First, it is necessary to collect more data (both cross-sectional and longitudinal) at the household level concerning demographic features, household economy (income and expenditures, material input/output), new household establishment, migration, and locations of both new households and fuelwood collection sites. These data could allow us to test hypotheses more rigorously in terms of plausible causal relationships (e.g., females' lower education could cause higher female outmigration through marriage). Such studies would not only be important to social scientists but could also be used to explain the dynamics of local biodiversity (represented by panda habitat in our study).

The impact of mortality and family planning factors on panda habitat may not be apparent for many years, as exemplified by the effects of an increase in marriage age on panda habitat. Thus, long-term studies of the factors presented in this chapter are essential. Spatial ABM (usually coupled with GIS) provides researchers with a useful tool to capture and integrate various detailed data – rather than just the averages – into a systems framework and overcome the shortcomings of traditional equation-based models. We conclude that this powerful experimental tool can promote a more complete understanding of long-term biodiversity dynamics across human-influenced landscapes.

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References

An L, Liu J, Ouyang Z, Linderman MA, Zhou S, Zhang H (2001) Simulating demographic and socioeconomic processes on household level and implications on giant panda habitat. Ecol Model 140:31–49

An L, Lupi F, Liu J, Linderman MA, Huang J (2002) Modeling the choice to switch from fuelwood to electricity: implications for giant panda habitat conservation. Ecol Econ 42(3):445–457

An L, Mertig A, Liu J (2003) Adolescents' leaving parental home: psychosocial correlates and implications for biodiversity conservation. Popul Environ 24(5):415–444

An L, Linderman MA, Shortridge A, Qi J, Liu J (2005) Exploring complexity in a human-environment system: an agent-based spatial model for multidisciplinary and multi-scale integration. Ann Assoc Am Geogr 95(1):54–79

Brashares JS, Arcese P, Sam MK (2001) Human demography and reserve size predict wildlife extinction in West Africa. Proc R Soc Lond Ser B Biol Sci 268(1484):2473–2478

China's Ministry of Forestry and World Wildlife Fund (1989) Conservation and management plan for Giant Pandas and their habitat. China's Ministry of Forestry and World Wildlife Fund, Beijing

Cincotta RP, Wisnewski J, Engelman R (2000) Human population in the biodiversity hotspots. Nature 404:990–992

Cooney RS, Shi J (1999) Household extension of the elderly in China, 1987. Popul Res Policy Rev 18(5):451–471

Fang RK (1993) The geographical inequalities of mortality in China. Social Sci Med 36(10): 1319–1323

Feng G, Hao L (1992) Summary of 28 regional birth planning regulations in China. Popul Res (Renkou Yanjiu; in Chinese) 4:28–33

Forester DJ, Machlis GE (1996) Modeling human factors that affect the loss of biodiversity. Conserv Biol 10(4):1253–1263

Hussain A (2002) Demographic transition in China and its implication. World Dev 30(10): 1823–1834

Lim K, Deadman PJ, Moran E, Brondizio E, McCracken S (2002) Agent-based simulations of household decision-making and land use change near Altamira, Brazil. In: Gimblett HR (ed) Integrating geographic information systems and agent-based techniques for simulating social and ecological processes. Oxford University Press, New York, pp 277–308

Liu J, Taylor WW (eds) (2002) Integrating landscape ecology into natural resource management. Cambridge University Press, Cambridge, UK

Liu J, Ouyang Z, Tan Y, Yang J, Zhang H (1999a) Changes in human population structure: implications for biodiversity. Popul Environ 21:46–58

Liu J, Ouyang Z, Taylor WW, Groop R, Zhang H (1999b) A framework for evaluating the effects of human factors ob wildlife habitat: the case of giant pandas. Conserv Biol 13:1360–1370

Liu J, Linderman M, Ouyang Z, An L, Yang J, Zhang H (2001) Ecological degradation in protected areas: the case of Wolong Nature Reserve for giant pandas. Science 292:98–101

Liu J, Daily GC, Ehrlich PR, Luck GW (2003) Effects of household dynamics on resource consumption and biodiversity. Nature 421(6922):530–533

Ma Z (1999) Temporary migration and regional development in China. Environ Plann A 31:783–802

McKee JK, Sciulli PW, Fooce CD, Waite TA (2004) Forecasting global biodiversity threats associated with human population growth. Biol Conserv 115(1):161–164

Mittermeier RA, Gil PR, Hoffman M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, da Fonseca GAB (2005) Hotspots revisited. Conservation International, Washington, DC

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858

Schaller GB, Hu J, Pan W, Zhu J (1985) The giant pandas of Wolong. University of Chicago Press, Chicago and London

Tan Y, Ouyang Z, Zhang H (1995) Spatial characteristics of biodiversity in Wolong Nature Reserve. China's Biodiversity Reserve 3:19–24 (in Chinese)

Veech JA (2003) Incorporating socioeconomic factors into the analysis of biodiversity hotspots. Appl Geogr 23(1):73–88

Wolong Nature Reserve (1997) Wolong Agricultural Operation and Contracting Situations (unpublished, in Chinese)

Wolong Nature Reserve (2000) Wolong 2000 Nationwide Population Census Form (unpublished, in Chinese)