CHAPTER 18

Lessons from Local Studies for Global Sustainability

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18.1 Introduction

An important feature of a model system is that the results from the system can be applicable to many other systems (Chapter 2). However, unlike model organisms such as the fruit fly (*Drosophila melanogaster*) and model ecosystems (Chapter 2), model coupled human and natural systems are more complex because they consist of both natural and human components as well as their interactions. Thus, generalizable findings from model coupled systems are often more difficult to obtain.

Fortunately, our team's long-term research in the model coupled system of Wolong Nature Reserve has been fruitful. Our work in this real-world laboratory has produced ideas and methods for understanding how coupled systems work and what this might mean for sustainability in Wolong and beyond. Besides providing useful information for conservation and sustainability policy making, these ideas and methods have also contributed to existing theories. Examples include theories on complexity (An et al., 2005), social norms (Chen et al., 2009), collective action (Yang et al., 2013a), and forest transition (Viña et al., 2011). Our work in this model coupled system has also contributed to the development of new theories such as those about telecoupling (Liu, 2014, Liu et al., 2013a, 2014, 2015, Liu and Yang, 2013; Chapter 17).

In the past two decades, our team has also learned many lessons through research in Wolong and through applying some of the results from Wolong to other coupled systems worldwide, as illustrated in previous chapters. Here we highlight ten of them. It is our hope that these lessons may be useful for studying other coupled systems and for helping achieve global sustainability.

18.2 Insights from model coupled systems are applicable to other systems

It has been documented that some aspects of coupled systems are different at different scales (scale dependent; Cumming et al., 2006, Zurlini et al., 2006) and in different contexts (context dependent; Abel et al., 2006, McDaniels et al., 2008). However, our team's work indicates that there are also some features of coupled systems that are the same or similar at different scales (scale independent) and in different contexts (context independent), in addition to scale-dependent and context-dependent features. This demonstrates the utility of model coupled systems like Wolong. In other words, methods and findings from a model coupled system can be applicable to other systems, including those in which the focal system is embedded and those that are far away from the focal system.

For instance, our finding that the number of households increased faster than population size in Wolong (Figure 18.1A) led to the discovery of a similar pattern in 141 countries (Figure 18.1B). This

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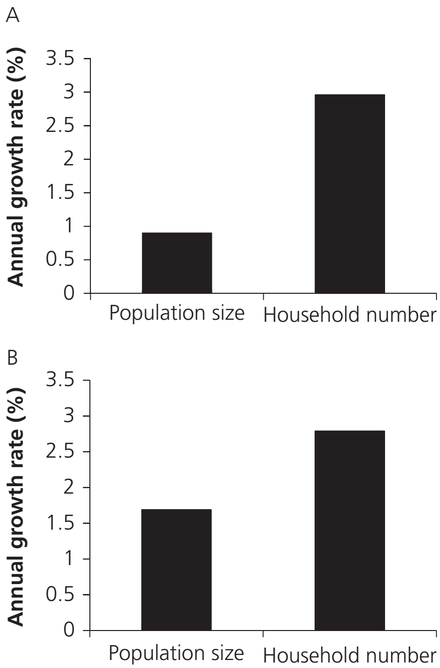

Figure 18.1 Increases in household numbers vs population sizes from 1985 to 2000 in (A) Wolong and in (B) 141 countries around the world.

pattern occurred not only at the reserve scale, but also at national and global scales. It occurred not only in the context of an agropastoral community in a protected area, but also in other contexts such as urban and suburban communities, in Western and non-Western cultures, and in forest, wetland, and grassland ecosystems (Liu et al., 2003a).

Because of these and other similarities across scales and contexts, some of the results and methods from work in Wolong have been scaled up to the entire giant panda range, the country of China, and the entire planet Earth (Figure 18.2). For example, they have contributed to broader studies on giant panda habitat dynamics across the species' range (Chapter 15; Li et al., 2013, Viña et al., 2010). They have also helped to understand China's environmental challenges (Liu, 2014, Liu et al., 2003b, Liu and Raven, 2010), ecosystem services programs (Liu et al., 2008, 2013b), and water sustainability issues (Liu and Yang, 2012). Insights from Wolong have broad implications for managing China's nature reserve system (Liu, 2013, Liu et al., 2003b) made up of approximately 2600 nature reserves (Liu et al., 2013b). For example, the decline of forest in Wolong Nature Reserve after its establishment (Liu et al., 2001) is similar to what happened in many other nature reserves (Curran et al., 2004, Maiorano et al., 2008), although their contexts differ.

Some methods that our team developed in Wolong have been applied to other coupled systems. For example, the agent-based model (ABM) developed for Wolong (An et al., 2005) has been adapted to Chitwan National Park in Nepal (An et al., 2014). Although Wolong and Chitwan are in different contexts (e.g., different countries), both have a

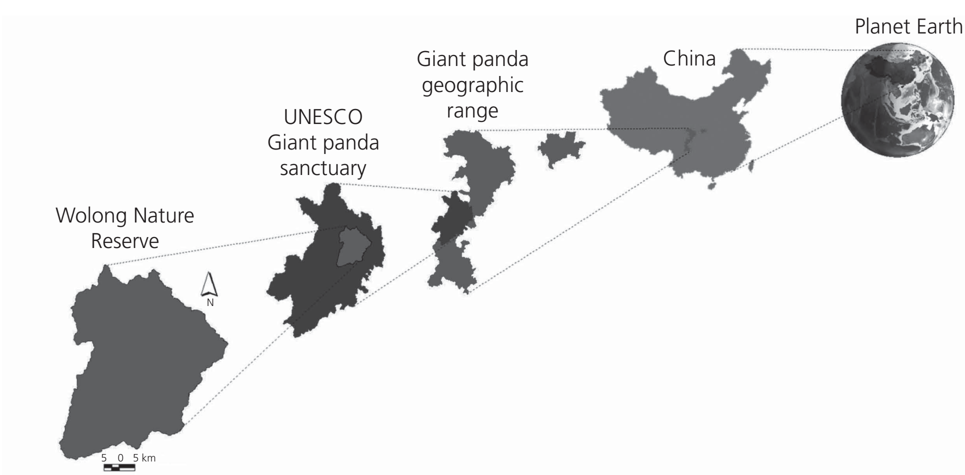

Figure 18.2 Scaling up from our model system in Wolong Nature Reserve to the entire planet.

similar hierarchical structure of agents (e.g., individuals, households, and communities) and similar types of human–nature interactions (e.g., marriage impacts household formation and, in turn, land cover; An et al., 2014). Insights into the complexity of Wolong have been used for cross-site syntheses with Chitwan (Carter et al., 2014; Chapter 16). Wolong and Chitwan have similarities in coupled system properties and dynamics. These similarities exist even though the two systems have different geographic settings (mountainous area vs plain), biological composition (e.g., pandas vs tigers), and demographic distribution (residents inside vs outside the protected area).

Wolong also shares many complex attributes (e.g., time lags, non-linearity, legacy effects, and heterogeneity) with other coupled systems around the world (Liu et al., 2007a). Such similarities exist even though the systems are located on different continents (Africa, Europe, North America, and South America). Those systems also differ in ecosystem types (tropical forests, agricultural highlands, lakes, urban, and wetlands), political structure (e.g., socialist or capitalist), human population density (from very sparse to dense), and economic conditions (developing vs developed).

Research in Wolong was the catalyst for the formation of the International Network of Research on Coupled Human and Natural Systems (CHANS-Net.org). This network serves as a platform for more than 1500 scholars from all over the globe interested in coupled systems research and applications to "see, be seen, find, and connect." Users share their project methods and ideas and alert the community to milestones and special events. The website received 6200 page views in its first year, 2009, and increased in the years following, reaching 17 900 page views in 2014. The network also has organized, convened, and/or sponsored 27 workshops and symposia on coupled systems research at major national and international scientific meetings (Table 18.1). In addition, a major component of the mission of CHANS-Net is to foster the careers of students and early-career scientists (CHANS Fellows). CHANS-Net supports them to attend, present, network, and learn from senior scholars at the various events. This program has sponsored 74 young scholars from all over the globe. The events have led to many fruitful interdisciplinary collaborations (e.g., Feola et al., 2015, Roy et al., 2013).

18.3 Humans and nature go hand in hand

The second lesson is fundamental to the core of coupled systems. It is that humans and nature go hand in hand. Our team's work in Wolong indicates that it is not possible for a given event in a system to affect only nature or only people, as there are cascading effects and everything is connected. Often, the interactions between humans and nature seem like a seesaw with the two subsystems on opposing sides but tightly coupled. Humans might degrade nature for their own gain in the short term, but might suffer in the long term due to feedbacks from changes in nature. On the other hand, nature might flourish under conditions when humans have moved away or their population has declined in a given area. Achieving sustainability of the entire coupled system requires a good balance of both sides. While a perfectly balanced "happy medium" between the two may appear to be a utopian fantasy, it is possible to achieve some degree of balance when both sides of the seesaw are adequately considered.

Human–nature conflicts and coexistence are common in Wolong (Chapter 4), as in many other parts of the world (e.g., Chapter 16). For example, collection of fuelwood in the reserve met an important need for people. But this practice was in clear conflict with giant panda conservation (Chapters 4, 7, and 10; An et al., 2001, Bearer et al., 2008). Emerging livestock-raising practices in the reserve also represent points of conflict for pandas and people. Livestock are a primary income source for people but can also directly compete with pandas for food and space (Chapter 4; Hull et al., 2014). On the other hand, there is also human–nature coexistence. Improvements in electricity from hydropower together with forest monitoring and payments from the Natural Forest Conservation Program (NFCP) helped change energy sources for people and minimize effects of fuelwood collection on panda habitat (Chapters 5, 7, and 13; An et al., 2002, Yang et al., 2013b). Participation in the Grain to Green Program and the Grain to Bamboo Program (GTGB) showed

Table 18.1 List of symposia and workshops organized, convened, and/or sponsored by CHANS-Net.

Name of symposium or workshop	Affiliate institution	Year and location	URL
Symposium on "Complexity in Human–Nature Interactions across Landscapes"	US Regional Association (International Association for Landscape Ecology)	2009, Snowbird, UT	http://www.usiale.org/snowbird2009/session_presentation.php?id=A1
Workshop on "Challenges and Opportunities in Research on Complexity of Coupled Human and Natural Systems"	US Regional Association (International Association for Landscape Ecology)	2009, Snowbird, UT	http://www.usiale.org/snowbird2009/index.php?id=halfWorkshops#complexity
Symposium on "Frontiers in Research on Coupled Human and Natural Systems (CHANS): Current Progress and Future Opportunities"	National Science Foundation headquarters	2010, Arlington, VA	http://chans-net.org/events/frontiers-research-coupled-human-and-natural-systems-chans-current-progress-and-future-opport
Symposium on "Coupled Human and Natural Systems in China and Nepal"	Global Land Project—Open Science Meeting	2010, Tempe, AZ	http://www.glp2010.org/
Seven different symposia on Coupled Human and Natural Systems Research	Annual Meeting of the Association of American Geographers	2010, Washington DC	http://meridian.aag.org/callforpapers/program/calendar.cfm?dn=1&mtgID=55
Six different symposia on Coupled Human and Natural Systems Research	American Association for the Advancement of Science	2011, Washington DC	http://chans-net.org/events/chans_aaas_2011
Workshop on "Land Change Meta-analysis"	Global Land Project	2012, Amsterdam, The Netherlands	http://chans-net.org/news/mapping-landscape-land-change-synthesis
Symposium on "Disentangling Diverse Drivers and Complex Dynamics of Coupled Human and Natural Systems (CHANS)"	US Regional Association (International Association for Landscape Ecology)	2012, Newport, RI	http://www.usiale.org/newport2012/sessions/symposium-nasa-msu-symposium-disentangling-diverse-drivers-and-complex-dynamics-coupled
CHANS-Net Workshop	American Geophysical Union	2012, San Francisco, CA	http://chans-net.org/news/chans-agu-2012
Four different Symposia on "Coupled Human and Natural Systems and Global Change"	American Geophysical Union	2012, San Francisco, CA	http://chans-net.org/news/chans-agu-2012
Two different Symposia on Coupled Human and Natural Systems	American Geophysical Union	2013, San Francisco, CA	http://chans-net.org/news/chans-net-members-gear-agu-again
Symposium on "Ecological Sustainability in a Telecoupled World"	Ecological Society of America	2013, Minneapolis, MN	https://eco.confex.com/eco/2013/webprogram/Session8773.html

promise for fostering gains for both people and pandas (Chapters 5 and 13; Liu et al., 2008, Yang et al., 2013b). These programs converted cropland to forest plantations and bamboo plantations, respectively. Ultimately, the seesaw is constantly shifting as new effects emerge and the two sides provide feedback to each other. For example, there is a potential increase in crop raiding by wildlife as a result of forest recovery (Chapter 13), which may lead to an increase in human–wildlife conflict. As human–nature interactions are dynamic, it is important to continue monitoring them and managing them adaptively.

18.4 Good intentions sometimes lead to bad outcomes

The third lesson is that good intentions can sometimes lead to bad outcomes. Managers working in difficult political climates try to put their best foot forward and make the best decision possible about how to manage a complex coupled system based on the information available. But sometimes not all of the information needed is available, especially in systems where not enough coupled system research has been conducted to inform such decisions. The dearth of information is particularly a challenge for human attitudes and mechanisms behind resource-use behaviors. These human dimensions are often overlooked in the management of natural resources (Leys and Vanclay, 2011, Liu et al., 2010).

Perhaps this issue can be illustrated with one of the first key findings of our research. We found that a faster decline in forest cover and panda habitat occurred after Wolong was established as a nature reserve (Liu et al., 2001). This finding had implications for protected areas worldwide by demonstrating that despite the best of intentions, a protected area designation does not necessarily protect biodiversity. The intention itself was not enough to produce a good outcome in the context of an ever-growing human population inside the reserve (not subject to China's national one-child policy). Other challenges that were difficult to overcome included a rapidly developing local economy, increasing tourism, and a lack of available energy source aside from fuelwood extracted from the forests (Liu et al., 2001). What the government overlooked in this protected area designation was the local context and the livelihoods of people living inside the reserve, which required other policies to manage them effectively.

Another example is a 1980s project of the Chinese government and the World Food Programme. This project sought to relocate farmers from the core panda habitat area inside the reserve to the main road by providing subsidized housing (Ghimire, 1997, Liu et al., 1999). The intention behind the project to relieve pressure on core panda habitat was good, but the outcome again was bad. The farmers did not move into the housing. The project sponsors did not recognize that if the farmers had relocated to the housing complex, they would be too far from their cropland (their primary lifeline). At that time, the farmers also would have had no other income-earning opportunities. These examples illustrate the importance of going beyond intentions. It is crucial to strive for sound conservation planning that considers all major aspects of the coupled system and anticipates all important potential outcomes in advance.

18.5 Put researchers in the local residents' shoes

The fourth lesson is to put ourselves in the local residents' shoes. Over the years, we took the time to get to know local community members by spending time in their homes and participating in their everyday lives and family events. By doing so, we began to see Wolong residents through their eyes and soak in the culture from their perspective. Our most meaningful insights came as a result of conducting thought exercises in which we put ourselves in the shoes of local farmers. We imagined ourselves navigating the complex labyrinth of changing policies, sudden disturbances, and shifting community and ecological dynamics in Wolong. We asked ourselves questions such as: Would we cut trees for fuelwood if we had no other way to cook food for our families and heat our homes? Would we raise horses as a new livelihood strategy if we were struggling to make ends meet? Asking ourselves questions like these and honestly commiserating over our answers helped us to see the coupled system more clearly. Ultimately, our answers showed that we would do things very similarly to what the locals have actually done. As a result, we stopped seeing local residents as objects to blame and began to understand that meeting their livelihood needs is at the very core of the sustainability of the coupled system as a whole.

This realization is what spurred us to focus on conservation incentives as ways of achieving conservation while also helping local livelihoods. It is not a fluke that incentive-based conservation programs have surged in popularity in recent years around the globe (Bulte et al., 2008). With a progressively developed global cash economy, humans residing in and around vulnerable coupled systems worldwide have substantial and often urgent economic needs (McShane et al., 2011, Turner et al., 2012). Putting oneself in the shoes of a local resident makes one realize that people need cash to feed their families, send children to school, pay for health care, and save for an uncertain future. Programs aimed at conserving nature by limiting the behaviors of people and their access to natural resources are not likely to succeed if these basic needs are not met (Swallow et al., 2009).

In Wolong, we saw the success of incentive-based conservation practices first hand. Where establishing the protected area alone failed to curb forest degradation, the incentive-based methods that prioritized local livelihoods appeared to succeed

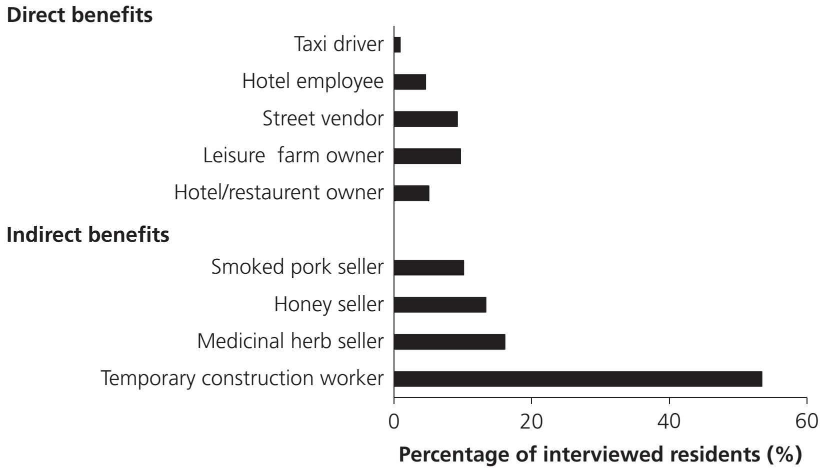

Figure 18.3 Percentage of interviewed local residents ($n = 217$) receiving direct and indirect benefits from tourism in Wolong in 2005–2007. Figure drawn from data in Liu et al. (2012).

(Chapter 6; Liu et al., 2008, Yang et al., 2013b). In addition to forest-cover increases, local people perceived and reported personal benefits from NFCP and GTGP/GTBP and expressed interest in re-enrolling if the programs were to be renewed (Chapters 11 and 13). One of the reasons that the incentive-based approach has worked well in Wolong is that the programs appeared to be well managed, and funds were fairly distributed with transparency. This sound management was not the case in many other areas where breakdowns in equity have occurred (Daw et al., 2011, Ferraro and Simpson, 2002). On the other hand, when we put ourselves in the shoes of the local people, we also saw that tourism in Wolong was suffering from an unequal distribution of benefits. Much less income was distributed among community members relative to outside companies (He et al., 2008). Few tourism jobs were available for local residents (Figure 18.3). Tourism was less successful than other strategies at helping both people and the environment (He et al., 2008, Liu et al., 2012).

18.6 Money isn't everything

The fifth lesson is that money is not the only factor that matters. Although money is important in shaping human behaviors, people are multidimensional. They have different cultural and family histories, religious and spiritual values, and ethical standards. People also have diverse sources of identity that relate to natural resources in different ways (Barrera-Bassols and Toledo, 2005, Colding and Folke, 2001). If these factors are not also considered, the coupled system cannot be fully understood or managed well.

The local residents that our team interviewed expressed strong cultural values and traditions, many of which were tied to behaviors we were studying. For instance, smoking pork using fuelwood was a strong cultural tradition of local residents that intersected with many important holidays (Yang et al., 2013c, Chapter 10). Many people with whom our team talked (especially older people) also expressed an inability to adapt to life outside the reserve in cities (even if given the opportunity). They preferred a more relaxed rural life against a fast-paced city atmosphere and preferred the higher environmental quality in the reserve to polluted cities. Our work on social networks also showed the strong family and community bonds among local residents, which often affected decision-making (Chapter 11; Chen et al., 2009, Yang et al., 2013b). Overall, local residents' attitudes and behaviors could not be easily predicted using a simple mathematical formula because they weighed multiple, sometimes competing interests at any given time.

18.7 Expect the unexpected

The sixth lesson we learned is to expect the unexpected. Surprises are a key component of coupled systems (Liu et al., 2007b). They happen because the systems are complex. Often a surprise may occur as a result of a past event in the system that was not previously considered, manifesting later as a legacy effect or a lagged effect. Other times a surprise may occur because the system has passed a threshold that was not anticipated, a sudden tipping point that throws the system into a new state. The challenge of anticipating or predicting the surprises may not always be possible, but can be helped by amassing long-term data and using them to develop systems models with scenario analyses (see Chapter 14 for examples).

In Wolong, one of the biggest surprises was how local residents responded to conservation policies in ways that were not anticipated and in conflict with policy goals. For example, NFCP involved a ban on timber harvesting. Many residents initially responded to this ban by cutting off branches of trees instead of the entire trunk for fuelwood. This behavior was not expected and was not addressed in the policy guidelines, but could compromise forest structure and suitability for wildlife (e.g., birds). Another related example is that some residents split up their households into smaller ones to receive more NFCP subsidies, which were handed out at the household level (see Figure 18.4 for the sudden jump in number of households in 2001 when NFCP started). Such behavior could work against the policy because more households and reduction in household size also increase the per-capita energy consumption, thus requiring more fuelwood (Liu et al., 2003a).

The emergence of raising horses was also a surprise because that had not been a part of local agricultural livelihoods in previous decades (Hull et al., 2014). The horses ate large amounts of bamboo in panda habitat, but the reserve managers were unaware of their presence for over a year. After our team informed the reserve managers about our research results, raising horses was banned. However, there was a surprising increase in raising other livestock species (e.g., sheep and yaks; Chapter 4). Our experience with studying the livestock suggests that a chain of surprises can occur. They can often emerge faster than the managers can come up with effective policies to deal with them. This phenomenon highlights the need for long-term research, monitoring, and adaptive management.

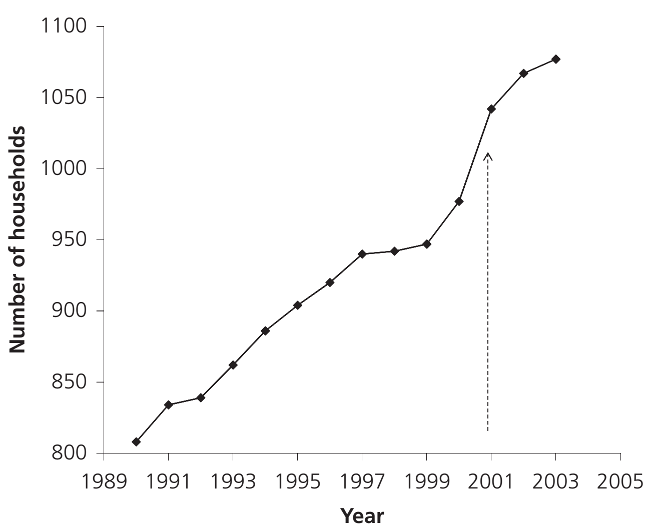

Figure 18.4 Household numbers in Wolong Nature Reserve over time, including a surge after the implementation of new conservation programs in 2001.

18.8 Diversify toolbox to meet complex challenges

The seventh lesson we learned is that researchers and managers should bring a diverse toolbox of ideas and approaches to the table when tackling sustainability in coupled systems. In our many years of work, we never found a "quick fix" or a simple solution to the challenges we encountered. From perusal of the literature, the same appears to be true in many other systems (e.g., Doremus, 2003, Underwood, 2011). This observation speaks to the complexity of coupled systems. We found instead that a mix of different factors helped explain a given phenomenon and a combination of different policies or management measures were needed to solve conservation challenges. This approach requires an ability to think creatively and integrate diverse perspectives.

In the early years of research on Wolong, it would have been easy to assume that the main problem was the number of people in the reserve. One might think that if the population could be controlled or limited, then perhaps the system could be sustained. However, our work suggests that it is not so simple. Given the failure of past household relocation attempts (Chapter 3), the best way to shrink population numbers in the reserve is to improve the education of young people so they can find jobs outside the reserve after graduation (Liu et al., 2001). That said, a single population regulation policy is unlikely to be a "quick fix" because our work has shown that other factors aside from population growth drive system dynamics. For instance, household proliferation (due to factors such as cultural shifts away from multigenerational households) is an even more important driver of environmental degradation than population sizes alone (Liu et al., 2003a). Education level, demographic makeup of the household (An et al., 2001), and social norms (Chen et al., 2009) are other factors that may also affect how people behave.

Ultimately, multiple different policies need to come together to achieve sustainability in Wolong. In addition to the education incentive, other approaches include incentive-based PES programs. We discussed many of the benefits from these programs in some previous chapters (e.g., Chapters 5, 7, and 13), and we believe they should be included as integral parts of the toolbox. However, the money earned from these policies cannot support a household by itself. It is simply not enough. Money earned from PES programs are supplements to household income (averaging US$143 per household/year from NFCP and US$571 per ha/year from GTGP; see Chapter 5, Yang et al., 2013b). These funds cannot serve as a household's entire income. Tourism is another item that should be in the toolbox of approaches to achieve sustainability, because tourism helps to diversify income generation for local people. However, tourism alone is not a solution because, as discussed in Chapter 12, the tourism industry is volatile and most local households benefit little from tourism.

Zoning is another policy that should be a part of the toolbox. Zoning allows protected areas with people living inside them to spatially segregate human development from core conservation areas (Hull et al., 2011). Without zoning, it is possible that human impacts could spread throughout the entire area and fragment key habitats. However, as discussed in Chapter 13, zoning is not a "quick fix." Zoning has only protected against infrastructural development in core conservation areas, but not against on-the-ground human activities such as livestock penetration into forests in Wolong that occur without an awareness or appreciation of zoning boundaries. The take-home message here is that each policy has strengths and weaknesses. Thus, a policy portfolio with multiple complementary policies is needed to tackle sustainability from different angles.

18.9 It's a marathon, not a sprint

The eighth lesson learned is that coupled system research is a marathon and not a sprint. The complexity involved in this type of research necessitates a long-term commitment. Scientific discovery is a non-linear process in that the most meaningful insights may not come to light until many years of research have been conducted. For instance, we learned a great deal about our model coupled system during its recovery after the unexpected earthquake hit the study area. This catastrophic event occurred after we had already been studying Wolong for 13 years. If we had stopped our study prior to this event, we would have missed the opportunity to learn many issues about the coupled system. Example research topics include vulnerability, resilience, and adaptability (Chapter 12), as well as the effectiveness of policies (Viña et al., 2011). In addition, the 13 years of data prior to the earthquake helped to strengthen our understanding of the profound shifts in the system after the earthquake (Yang et al., 2013c, 2015, Zhang et al., 2011, 2014). Taking a long-term approach also allowed us to examine the trajectories of various human and natural components. Furthermore, it created causal chains explaining how and why different phenomena occurred, such as how conservation policies shifted labor allocation over time or why people decided to out-migrate or engage in new income-generation activities.

There are considerable barriers to obtaining funding to support such long-term research via traditional funding channels. It is ironic that sustainability is a long-term issue and coupled systems are very dynamic, but funding for research on sustainability is often short lived. The trend in the research community with increasingly limited funding appears to reward short-term, low-risk projects aimed at producing rapid results. However, this trend is at odds with another major funding goal to support transformative research. Transformative research is "research creating radically innovative insights and effectively contributing to solutions for the severe sustainability problems facing our society" (Wiek, 2010). In our experience, most transformative research on coupled systems requires a long-term effort.

One solution to this disconnection between long-term transformative research needs and short-term funding limitations is to conduct coordinated relay research under a comprehensive long-term framework. Like a relay race in sports, relay research is a central part of our philosophy of long-term work on the model coupled system. It involves splitting up a large body of planned work into multiple, smaller projects assigned to different team members (e.g., students or postdoctoral researchers). The projects should all fall under the same general framework, but can be distinct from one another and fit together like unique but integrated puzzle pieces. For instance, early in our research, we had one student working on socioeconomics and another student working on remote-sensing approaches to understand forest-cover change. Both students collaborated to produce integrated results (An et al., 2001, Linderman et al., 2006). Housing the data in a common platform (e.g., the Inter-university Consortium for Political and Social Research, ICPSR; ICPSR, 2014) can assist in integrating findings. Such an arrangement can in turn help foster collaborative work among different generations of team members over long time periods.

18.10 Think "outside the box"

The ninth lesson we learned is that it is important to consider any given coupled system in a broader context that extends outside the perceived study area boundaries. In other words, think "outside the box." Any given coupled system is actually a part of a network of multiple coupled systems that are connected to one another by flows (e.g., movement of information, energy, people, goods, or organisms). No system can be fully understood in isolation (Liu et al., 2015). Considering outside influences as drivers of change or impacts on other systems as externalities only does not do the system justice because it ignores the feedbacks between the focal system and other systems. The telecoupling framework allows for these interactions among coupled systems to be explicitly integrated (Chapter 17; Liu et al., 2013a).

As documented in Chapter 17 and several other chapters, Wolong may be small in area, but its impact is large and stretches across the entire globe. Besides internal factors, dynamics in Wolong are driven by agents, flows, and causes originating in other systems via telecouplings. Examples include information flow, national conservation policies, tourism, agricultural markets, and panda loans (Chapter 17). Wolong is a receiving system for tourists and money from agricultural trade, tourism, and conservation policies. In turn, Wolong is a sending system for pandas, agricultural products, and information. The importance of telecoupling as a means of thinking "outside the box" cannot be overstated. In fact, our work in Wolong demonstrates that telecouplings sometimes can be even more important than local couplings in driving system dynamics.

This observation is perhaps best appreciated by our findings documenting the impact of the earthquake, which cut off many telecouplings between Wolong and the outside world and in turn threatened human livelihoods inside Wolong (Chapter 12). Researchers need to explicitly account for and quantify telecoupling agents, causes, flows, and effects. Such quantification would help to better anticipate responses to such perturbations and provide guidance for how to overcome sustainability challenges (Liu et al., 2015).

18.11 Engaging stakeholders can foster positive change

The tenth lesson we learned through our research is that reaching out to stakeholders to share findings and make recommendations for the future can foster positive change. Our team has worked closely alongside the managers of Wolong over the years and has had meaningful reciprocal interactions with them that have benefited both sides. This relationship was worthwhile even when research findings did not reflect positively on the management. For instance, the government agencies at first did not believe our finding that there was faster habitat degradation in Wolong after the reserve was established (Liu et al., 2001). Through sharing objective results and expressing genuine respect for the challenges they faced, we are delighted that several management changes were made and panda habitat has been recovering (Viña et al., 2007).

We have also worked together with local residents, researchers, and government officials in Wolong over the years in other ways. On one hand, we have received logistical support and knowledge from the local residents, researchers, and administration. On the other hand, we have shared our techniques, approaches, and data through daily interactions, guest lectures, and workshops with the local researchers and managers. We have also hosted several local researchers for training and collaboration at our research center at Michigan State University in the USA. Overall, we have found that the management community especially appreciates the trust that has been fostered due to our long-term commitment year after year to send students and faculty to work in Wolong. This trust has been valuable in a time when many organizations appear for short-term periods only to disappear soon after—a pattern that prevents long-term trust and consistency from being developed.

We feel that it is also rewarding to reach out to the public to share our experiences and research findings. Over the years, our team has given countless guest lectures at university campuses, local K-12 classrooms, and other public forums. We have also engaged in interactions with the news media (e.g., *The New York Times*, BBC, *Time* magazine, and China Central Television—CCTV) and social media. We have found that members of the public are eager for information and also ask pointed questions that challenge us to think more broadly and deeply about our work. Because coupled systems are complex, it is all the more fruitful for us to reach out and share our findings.

The story of Wolong is an engaging one that captures people's attention. We try to harness people's fascination for Wolong to convey broader ideas about sustainability. We want the public to understand that humans are not isolated but are a part of a larger system that includes nature. It is our hope that the story of Wolong helps people comprehend that everything humans do affects nature and affects the sustainability of the planet Earth, which in turn affects humans. It is important to create win–win solutions to sustain the environment and improve human well-being. Ultimately, we want to convey a hopeful message emphasizing that when there are deleterious patterns, it is essential to change human behaviors to ensure that resources are sustainably managed for future generations.

18.12 Summary

Our team's two decades of interdisciplinary research in Wolong Nature Reserve and beyond has revealed many complexities of human–nature interactions. Here we have summarized ten overarching lessons from our research in Wolong and its applications to other coupled human and natural systems. Our results indicate that Wolong is a valuable model coupled system as methods and findings from Wolong can be applicable to larger systems in which it is embedded and to other systems worldwide. Seeing the system from the multifaceted perspective of local residents in Wolong allowed us to better appreciate the difficulties that residents face and the diverse and dynamic factors (e.g., not only economic, but also cultural, social, and political) that they consider in making decisions. We also found that good intentions can sometimes lead to bad socioeconomic and environmental outcomes. It is essential to take a long-term approach to reveal complex attributes such as time lags, legacy effects, and feedbacks. Working with managers has given us an appreciation for the management problems they face and a platform from which to use our research to foster positive change. For example, we found that multiple interacting policies were needed to effectively manage human–nature interactions for sustainability. Other lessons include thinking "outside the box," diversifying the toolbox of ideas and approaches to meet complex challenges, and expecting the unexpected. We hope these lessons are useful for others undertaking the challenging, yet rewarding, task of conducting long-term, interdisciplinary research on coupled systems around the globe.

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