APPLIED BIODIVERSITY SCIENCE: BRIDGING ECOLOGY, CULTURE, AND GOVERNANCE FOR EFFECTIVE CONSERVATION

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SUMMARY

Solutions to the biodiversity crisis will ultimately come from biological scientists and social scientists working in tandem, yet disconnects among scientific disciplines, conservation institutions, and practical implementation hinder effective conservation. The vision of Applied Biodiversity Science (ABS) is to achieve integration between biodiversity research and on-the-ground conservation practices. Three pillars support ABS: 1) integrated social and biological research; 2) cross-disciplinary collaboration with local conservation institutions and actors; and 3) application of conservation theory to practice. Our ABS program, including a doctoral training program, is focused on two cross-cutting themes: Ecological Functions and Biodiversity; and Communities and Governance. The research integration matrix matches causes of biodiversity loss against research approaches, and is thus a useful tool for defining integrative questions and building interdisciplinary research teams. Case studies from Western Amazon and Gran Chaco illustrate how the ABS model has been implemented in the Americas. The intention is that ABS approaches will produce conservation scientists who communicate effectively across disciplines, and make their research relevant to ongoing programs. The ABS approach helps elucidate how and why ecosystem functions, biodiversity, human communities and governance systems are interconnected.

Efforts to halt the loss of biodiversity must be based on integration between science and practice. Linking theory with real-world conservation requires collaboration among universities, museums, governments, NGOs, communities, and the private sector. Such collaboration is used to prioritize areas for conservation (Myers *et al*., 2000), aid in reserve design (Terborgh *et al*., 2002), develop socially acceptable management plans (Harmon and Putney, 2003), build local capacity for stewardship (O'Riordan and Stoll-Kleemann, 2002), and guide policy for sustainable use, ecotourism, and other integrated strategies for conservation and development beyond the borders of protected areas. Currently, a great deal of conservation research is based in universities with few linkages between scientists and practitioners, or between theory and practical strategies for conservation. New approaches are needed that put scientists from multiple disciplines to work confronting the complex challenges of conserving biodiversity and ecosystem services throughout the mosaic of land uses at national or regional scale (Sayer and Campbell, 2004; MEA, 2005a).

What are the barriers to integrative team-building between biological and social scientists, when both share the same goals of biodiversity conservation and sustainability? In the 20th anniversary issue of *Conservation Biology*, researchers from numerous disciplines ranging from anthropology to zoology called for greater collaboration to address the loss of biodiversity, "the most vexing and serious problem ever to face humanity" (Meffe *et al*., 2006). Noted Mexican biologist José Sarukhan (2006) wrote, "Conservation cannot be achieved without the soundest information from the natural and social sciences." A persistent issue is the lack of discourse among social and natural scientists about why social effects matter and how methodologies can be designed to take social beliefs and practices into account prior to management interventions (West and Brockington, 2006).

Specialized (single-discipline) doctoral research programs, frag-

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mented graduate curricula, and lack of formal frameworks for interdisciplinary collaboration and graduate training impede doctoral students in conservation science and hinder development of the kinds of scientists recruited by the international conservation community (Reid *et al*., 2002). The Society for Conservation Biology website lists 534 academic programs with 2255 faculties (www.conbio.org; accessed Oct 2, 2008). These programs go by various names and are scattered among departments of Biology, Wildlife Science, Forestry, Anthropology, Sociology, and other departments in colleges of science, liberal arts, agriculture, and forestry. Moreover, the bulk of these programs are traditionally structured, and may not have favored development of integrative programs in conservation.

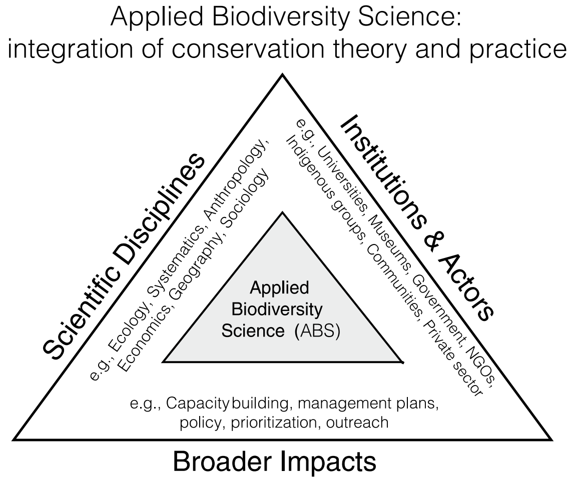

Figure 1. Applied Biodiversity Science (ABS) is the integration of theory and practice among three pillars: multidisciplinary research, collaboration among institutions, and application to conservation.

Not surprisingly, prominent conservationists continue to lament how few conservationists have been trained to work across disciplines in biodiversity sciences (Jacobson and McDuff, 1998; Méndez *et al*., 2007). Noss (1999) pointed out that, "Although conservation biology professes to be interdisciplinary … the vast majority (Society for Conservation Biology members and authors) are traditionally-trained biologists whose abilities in management and policy are self-taught or acquired by painful experience." Throughout the world conservation scientists continue to strategize about how to make their work directly and easily applicable to policy (Rodríguez, 2009). Interdisciplinary cross-training among natural and social scientists is needed to facilitate integrative policy solutions.

Despite the academic and fiscal roadblocks to interdisciplinary team research, integrated approaches to conservation do occur (Fitzgerald, 1994; Brightsmith *et al*., 2008; Killeen, 2007) and there are some good models for building integrated graduate education in tropical conservation and development (Inouye and Brewer, 2003; Zarin *et al*., 2003; Kainer *et al*., 2006; Morse *et al*., 2007). Not surprisingly, the architects of all these programs call for more integrated training in biodiversity conservation and new approaches for building multidisciplinary teams in conservation research.

The vision for integrative applied biodiversity conservation research presented here includes an operational framework for defining integrative questions and forming interdisciplinary research teams in applied biodiversity science. An overview of current conservation challenges in two regions in South America, the Western Amazon and the Gran Chaco, illustrates how the Applied Biodiversity Science (ABS) vision is being implemented.

An Integrative Vision: ABS for Effective Conservation

Applied Biodiversity Science (ABS) is aimed at integrating basic biodiversity research and conservation. ABS is supported by three main pillars (Figure 1): Scientific Disciplines: disciplinary research in social and biological sciences, Institutions and Actors: research and collaboration with conservation institutions and actors in the field, and Broader Impacts: the application of conservation theory to practice. The ABS approach to biodiversity conservation hinges on simultaneous consideration of ecological functions of local ecosystems, the activities, attitudes, and needs of surrounding communities, as well as wider social, economic, and political contexts.

Because most biodiversity exists in developing countries in the tropics, a challenge for conservationists is balancing ecological goals with social, economic, and political imperatives. This makes achieving biodiversity conservation in the tropics (and elsewhere) an interdisciplinary endeavor that requires combined input from scientists and practitioners in the fields of ecology, systematics, economics, sociology, geography, anthropology, and others. The complexity of biodiversity conservation presents a daunting challenge to graduate students and their mentors, as well as to progress of the science itself.

Compounding the problem of biodiversity scholars working in isolation is the fact that scientific theory seldom translates to effective on-the-ground conservation. Training students exclusively at universities often fails to provide opportunities to realize the broader impacts of their intellectual endeavors. Classically trained biologists have a surprising lack of understanding about how biodiversity information can be applied to conservation efforts, or how socioeconomic factors ultimately influence conservation policies. Conversely, many practitioners in sustainable development, ecotourism, and other strategies for conservation are uninformed on basic theories in ecology such as species-area relationships, diversity gradients, and speciation. These gaps highlight the need to integrate theories and methods from a diverse set of disciplines and improve methods for channeling scholarly research into conservation.

Biodiversity scientists with skills in interdisciplinary research and collaboration are in demand in academia, NGOs, and federal agencies throughout the world. In the USA "Over one-half of the Senior Executive Service (SES) members at the Department of the Interior (DOI), USDA Forest Service, and Environmental Protection Agency (EPA) will retire by 2007. …DOI will lose 61 percent of its program managers, the Forest Service will lose 81 percent of its entomologists and 49 percent of its foresters, and EPA will lose 45 percent of its toxicologists and 30 percent of its environmental specialists" (RNRF, 2003). Meanwhile, scientific understanding is limited among decision makers. In 2005, the US Congress contained 218 lawyers, 12 doctors, and three biologists (Kristof ND, The hubris of the humanities. NY Times, Dec 6, 2005: A19). Discovery-based research in biodiversity and biological complexity are priorities at US agencies, including the NSF. Large NGOs (e.g., WWF, WCS, Conservation International) have also realized this need in the Northern Hemisphere and throughout the developing world, and support conservation interventions that are based on integrative social and biological science research.

Integrating Biological and Social Science Research Themes

The problem with poor communication, coordination, and comprehension among researchers/scholars is that data and research findings can not be readily applied to real-world conservation. An integrative framework for biodiversity conservation research relies on an *a priori* approach of simultaneously incorporating complementary research in biological and social science, while working with local institutions and actors from the outset to address common root causes of biodiversity loss and environmental degradation.

Teams working in ABS are focused on two cross-cutting themes: ecological functions and biodiversity; and communities and governance. Research teams use the three-pillar ABS approach (multidisciplinary research, collaboration among institutions, and application to conservation) to integrate scientific findings with practical conservation efforts by local institutions and actors. Positive feedbacks of researches in the major themes and the application of scientific findings to conservation, effectively integrate the three pillars of the ABS model.

Ecological functions and biodiversity

Ecosystem services upon which human welfare and survival depend rely on properly functioning ecosystems (NRC, 2004; MEA, 2005b). Resilience is a critical characteristic of healthy ecosystems, and biodiversity is a key determinant of ecosystem resilience (Holling, 1973; Webb, 2007). By identifying underlying interactions among ecosystem components, scientists will better understand the mechanisms that produce important ecological services, and thus more accurately calculate the intended outcomes and feasibility of management actions (Jeppesen *et al*., 1998). ABS faculty research programs draw from fields of population and community ecology, ecological morphology, phylogenetic systematics, behavior, landscape ecology, and biodiversity assessment to address various conservation issues, such as habitat requirements of single species, determinants of local and regional diversity, and mechanisms determining the fate of invasive and native species. Better understanding of the linkages between biodiversity and ecosystem function is critical to facilitate ecologically meaningful policy decisions.

Research in ecological functions and biodiversity is aimed at the following types of questions: What local and historical processes determine presence and distribution of biodiversity? How is biodiversity tied to ecological function and how are both altered by what people do? What mechanisms are influencing the fit between organism and environment?

Communities and governance

This theme focuses upon the study of conservation as a social process, the success of which depends on participation and cooperation of local communities, government agencies, NGOs, indigenous federations, scientists, and the private sector (Brosius *et al*., 1998; Dearden *et al*., 2005). Each interest group has its own set of priorities, visions, and perspectives for addressing conservation. These inherent differences, magnified by power disparities, can be major obstacles to collaboration. Thus, greater understanding of politics, institutions, and incentives of multiple actors at different scales is critical for effective conservation (Painter and Durham, 1995). Agrawal and Ostrom (2006) have argued that understanding and strengthening governance systems at relevant scales is perhaps "the most important challenge of the next century for biodiversity conservation."

Research in *Communities and Governance* addresses the following types of questions: How do political, economic, and historical relations of power and inequality at different scales explain uses and values of biodiversity? How do institutional and organizational arrangements affect access, use, and protection of biodiversity? Under what conditions can adding economic value to biodiversity create incentives for conservation (e.g., ecotourism, non-timber forest products, sustainable use of wildlife and fisheries)?

Causes and consequences of biodiversity loss addressed		Research expertise within and across the two primary research themes — Research approaches: A Ecological functions and biodiversity				B. Communities and governance			
		Biodiversity assessment	Population & community ecology	Evolutionary, phylogenetic, behavioral studies	Landscape ecology	Historic & ethnographic studies	Demographic studies	Participatory & community-based studies	Ecological & resource economics
A. Ecological functions and biodiversity	Land-use change & habitat loss	I	I		I	X	X	X	X
	Invasive species	I	I	I			X		
	Declining range size & diminishing populations	I	I	I	I				
	Environmental degradation	I	I	I	I		X		X
B. Communities and governance	Inequalities in biodiversity access				X	—	—	—	
	Poverty & social conflict				X	—	—	—	—
	Over-exploitation		X	X		—	—	—	—
	Deteriorating governance structures & policies	X			X	—	—	—	

Figure 2. The research integration matrix is a tool to identify opportunities for integrative research spanning biological and social science research themes in applied biodiversity science. Research approaches (columns) are applied to causes and consequences of biodiversity loss (rows) in both Major Research Themes. Upper left and lower right quadrants of the matrix indicate potential for research from allied disciplines in each major research theme. Vertical bars denote contributions in theme A; horizontal bars in theme B. Upper right and lower left quadrants, with boxes marked by X, illustrate key opportunities for novel integrative research that bridges both major research themes. Empty boxes represent opportunities for new integrative research by teams of ABS scholars. Teams of ABS scholars use the matrix to bring perspectives from biological and social sciences to the same set of conservation problems with complementary research.

A Matrix Approach to Research Integration in ABS

Achieving integration and complementarity in research is not automatic. Building integrative research programs requires communication among scientists from diverse disciplines and a focused problem. A key mechanism to achieve the vision of ABS revolves around researchers in biological and social sciences working together and with the same local institutions and actors from the beginning of the process in order to achieve broader impacts of their research. A research integration matrix was designed to juxtapose some causes and consequences of biodiversity loss against the research approaches used to study these problems (Figure 2). Research integration matrices developed with participants from various disciplines and local institutions thus serve as a tool for building constructive feedbacks among disciplines, local institutions and broader impacts for conservation.

The causes of biodiversity loss and associated research approaches listed in the matrix are not comprehensive nor intend to apply to all situations. In formulating an integration matrix, the research approaches (columns) listed are constrained by the spectrum of conservation problems under consideration and the expertise of the pool of researchers. The causes and consequences of biodiversity loss (rows) are those that can be addressed by the research program, and may include a combination of proximal and ultimate causes. The research integration matrix presented here does not list climate change, for example, because this particular research program in ABS does not include research on ecological functions and governance structures related to climate change.

In the research integration matrix, individual cells represent endeavors filled by researchers making solid disciplinary contributions to a conservation problem. A resource economist may undertake a study related to invasive species, and this research would occupy one of the cells in the far-right column in the matrix. A result of developing integration matrices is that in many instances (bars in Figure 2), teams may already have a strong track record of integration. The striped areas of the matrix under each research theme represent research from allied disciplines working on a common conservation problem. The vertical bars represent research strengths in the fields of conservation biology. For example, researchers who specialize in biodiversity assessment, community ecology, and landscape ecology apply their research to understanding land use change and habitat loss. Horizontal bars correspond to research among conservation social scientists who use historical or ethnographic methods, or participatory community-based approaches, to study issues of poverty, social conflict, and inequalities in access to resources.

Filling the boxes: Integration in ABS

Achieving the vision of ABS requires the creation of stronger linkages and further integration among biodiversity scientists. The upper right and lower left quadrants in the matrix represent some of the most persistent disconnections in the field of biodiversity conservation science, and illustrate key opportunities for assembling new integrative research teams and for doctoral dissertation research. Building a community of scholars in ABS who will "fill the boxes" entails bringing perspectives from social science to answer questions relevant to the ABS theme of ecological functions and biodiversity and conversely, sharing methods and insights from biological sciences to inform research in communities and governance.

Hence, the vision of ABS entails complementary research that bridges both research themes; that is, addressing problems across the entire matrix, not just in the shaded areas. An ABS approach to the pervasive issue of overexploitation (with negative feedbacks to poverty, access, and equitability) would therefore employ complementary research approaches in both ecological functions and biodiversity, and communities and governance. A complementary set of studies might use approaches from landscape ecology to understand the spatial and behavioral consequences for species that are hunted for subsistence and commercial use. One group could study the conditions under which certain species are more or less suitable for sustainable use, while another could explore the impacts of markets upon hunting. A third could assess land-use to determine the size of indigenous reserves suitable for subsistence-based harvesting, and a fourth could evaluate how hunters select prey and the processes by which decisions change over time.

Similarly, the empty box in the matrix that represents the intersection between participatory/community-based studies and environmental degradation identifies a research opportunity. Collaboration among biologists and anthropologists, for example, could produce complementary research related to community-based biomonitoring of indicators of health or disturbance of an ecosystem caused by invasive species. The biologists would use their findings to design ecological monitoring protocols, and then in collaboration with anthropologists could develop and implement community-based monitoring. In tandem, the anthropologists could evaluate the efficacy and level of acceptance or rejection by local residents. The application to conservation would be to build the capacity of local communities to measure and monitor environmental conditions and invasive species.

Operationalizing ABS: Case Studies

Most site-specific challenges of biodiversity loss are microcosms of larger challenges associated with economic disparities, market-driven exploitation, resource management policies, and cultural norms. Throughout the world, networks of anthropogenic landscapes, land-use mosaics, and protected areas, including communities (from subsistence to urban) are engaged in conservation and resource use through varying forms of governance (Armitage *et al*., 2009). Such is the case in the Western Amazon and Gran Chaco of South America, where long-term research has been conducted in partnerships with communities, governments, and NGOs (Fitzgerald, 1994; Stronza, 1999). Despite commonalities, there are striking differences between the areas with respect to biological, cultural, socio-economic, and institutional characteristics. In addition, resource management challenges and international perceptions of conservation priorities vary. For example, the Western Amazon is considered a biodiversity "hotspot," while the Gran Chaco receives less attention because of its relatively low species richness and endemism (Mares, 1986). Although ultimate causes of biodiversity loss (e.g., land use change, invasive species, poverty) play a role in each region, the proximal causes and interactions play out differently in each area.

In the ABS model presented here, research teams working within both major research themes (ecological functions and biodiversity and communities and governance) address the multifaceted causes and consequences of biodiversity loss and potential conservation applications in the research areas. Each researcher's disciplinary contribution can be linked to others as they share the broader impacts for biodiversity conservation, and these broader impacts were anticipated and discussed from the inception of the integrative research program.

The ABS approach can be used to generate comparative data for testing whether or not conservation strategies may be transferable among regions. For example, community-based ecotourism seems to be working in the Western Amazon, but is less likely to be an economically viable conservation strategy in the harsh thornforests of the Gran Chaco. Sustainable use of wildlife and indigenous co-management of protected areas are elements of conservation success in the Chaco (Arambiza and Painter, 2006), yet these approaches may not be applicable in other areas, especially where land tenure regimes are unstable. The ABS framework provides research teams with opportunities to "fill the boxes" by building on previous work and taking advantage of partnerships to focus complementary research using the integration matrix. Additionally, the ABS framework allows differing perspectives to emerge, and comparison of findings both within and among areas.

Conservation challenges in the Western Amazon

The Western Amazon basin is one the most biologically diverse re-

Figure 3. The Western Amazon of Peru is a biodiversity hotspot, with over 5×10^6ha of government protected areas (left). Ecotourists looking for hoatzins and giant otters in Tres Chimbadas oxbow lake, Tambopata, Peru (center) bring revenue, employment, and new opportunities to local communities, thus adding value to rainforest biodiversity. Indigenous leaders from Ecuador, Peru, and Bolivia met over a series of workshops in 2003 to exchange lessons learned in ecotourism management (right). Photographs: Amanda Stronza.

gions on earth (Foster *et al*., 1994; Mittermeier *et al*., 2004) and is marked by great human diversity, including uncontacted indigenous peoples, legally-titled indigenous communities, second-generation *ribereños* and *mestizos*, Aymara and Quechua-speaking colonists from the highlands, and international ecotourists (Chicchon, 2001; Stronza, 2008; Figure 3). It is one of the most pristine regions in the Americas, largely due to lack of transportation and access. There are over 5×10^6ha of government protected areas, a size greater than the total land area of Costa Rica. It includes the Bahuaja-Sonene National Park and Manu National Park in southeastern Peru. However, threats from logging; gold mining; over-harvesting of game, fish and forest products; expansion of ranching; coca cultivation; and wildlife trafficking are continually increasing (Álvarez and Naughton-Treves, 2003; Killeen, 2007).

People are also being impacted. Indigenous and long-established communities face challenges of new settlers claiming the territories. There is little support from regional and national governments, poor access to credit and extension services, low prices and unstable markets for produce, poor education, health and transportation infrastructures, and loss of cultural identity in the rapidly modernizing area (Coomes and Barham, 1997). Recent plans for the trans-oceanic highway connecting the heart of the Peruvian Amazon to markets in Lima and Brazil threaten to end the isolation that has protected this area (Naughton-Treves, 2004). Similar plans exist to connect cities to the western Amazon in Bolivia, a change that will have ecological and social ramifications in the coming decades. In some areas this process is just beginning, and there is time to mitigate some of the effects of road building.

Complementary ABS research

Ecotourism has exploded in parts of the region, bringing the promise of diversified economic alternatives and livelihoods, along with the possibility of unregulated growth negatively impacting local cultures, communities, and wildlife (Kirkby *et al*., 2000; Stronza, 2001). Teams of researchers from diverse disciplines working in conservation can take advantage of opportunities to integrate social, economic, and ecological analyses of ecotourism. One of us (ALS) has worked with farmers, indigenous federations, tourism operators, and local communities in the Tambopata region since 1993, studying impacts of ecotourism on local livelihoods, natural resource use, and cultural identity (Stronza, 2007). A major focus is change in governance and community-based institutions for conservation that result from ecotourism. Biologists working at the sites use ecolodges as research stations to conduct conservation-biology research (Brightsmith *et al*., 2008). Brightsmith (2005) directly investigated effects of ecotourism on population and community ecology of macaws, parrots, and other avifauna.

Aquatic biodiversity is critically important for human welfare throughout Latin America since inland fisheries in tropical regions provide a cheap source of animal protein for low-income people in rural and urban areas (Allan *et al*., 2005). An integrative study on the impacts of mercury-based gold mining on aquatic ecosystems, for example, would address a major conservation and human health problem in the region. Comparison of the impacts of ecotourism on local people and its impacts on wildlife, relative importance of different economic activities in local communities and their potential, and economic evaluations of fish management *vs* gold mining for local people are a few examples of specific research needs in the Western Amazon that can be identified using the ABS approach. Other complementary studies in the region, which draw on research expertise in both research themes would be fed directly back to collaborators and other stakeholders through networks and relationships established during long term involvement in the area.

Large-scale development projects like the trans-oceanic highway threaten to open wilderness areas of the Amazon for colonization and exploration (Killeen, 2007). Emergent collaborations among teams working together to synthesize the impacts of land fragmentation on biodiversity at multiple spatial scales will be able to explore alternatives to road-related unsustainable resource exploitation. In turn the findings will link to the formulation of conservation priorities and policies through the broad array of established regional collaborators.

Conservation challenges in the Gran Chaco

The Gran Chaco, in Paraguay, Bolivia, and Argentina, is a tropical dry forest and the third largest biome in South America (Bucher and Huszar, 1999). Deforestation rates at the Gran Chaco equal or exceed global trends (85% of original lowland and montane Chaco forests were cleared over the last 30 years; Zak *et al*., 2004). The abundant local biodiversity has been under-appreciated by the conservation community, perhaps because species numbers are higher in Amazonia, and media focus is on rainforests. In fact, Neotropical drylands support more endemic mammals than does Amazonia (Mares, 1986) and species richness of mammals >1kg in the Chaco is almost as high as in the most specious Amazonian sites (Redford *et al*., 1990).

Land use varies among the three Chaco countries, creating a panorama for studying and understanding impacts in relation to different economies, development histories, and national policies. Deforestation for ranching, agriculture, and fuel led to the conversion of much of the Argentine Chaco by the mid-20^{th} century, primarily because of the demand for beef for European markets, and demand for railroad ties and fuel for the Argentine railroad system (Schofield and Bucher, 1986; Grau and Brown, 2000). What remains of the Argentine Chaco is largely a fragmented mosaic of land uses.

Ranching and unsustainable agriculture are also problematic for the Chaco forests in Paraguay. The Paraguayan Chaco remained largely unsettled until the 1980s, with the excep-

Figure 4. Much of the Gran Chaco in Argentina, Paraguay, and Bolivia is semi-arid thorn forest (left). Deforestation, over-hunting, and over-grazing results in a degraded landscape with reduced plant and animal diversity that is barely suitable for livestock (center). In Bolivia, in collaboration with the *Capitanía del Alto y Bajo Isosog* and WCS, indigenous parabiologists like Florencio Mendoza (right) study the biodiversity they live with and use, and implement sustainable use management plans. Photographs: Lee Fitzgerald.

tion of the Menonite colony of Filadelfia established in the 1920s. The rapid expansion of Filadelfia and neighboring Menonite colonies in the 1980s led to deforestation, rapid salinization and desertification. Menonite leaders are now implementing sustainable land use practices. Forest clearing in Paraguay is also associated with the trans-Chaco highway. Efforts have been initiated to link national parks in the Paraguayan Chaco with adjacent conservation areas in the Bolivian Chaco.

Parts of the Bolivian Chaco remain relatively isolated and undeveloped, but extensive areas have been deforested for export-led soybean cultivation, and by Menonite colonies and Bolivian and expatriate ranchers. The result is environmentally unsustainable modern agriculture alongside economically unsustainable traditional resource-use systems. Rapid changes are resulting from the Bolivia-Brazil gas pipeline (Pató, 2000) and associated rail and road links. The Bolivian Chaco is known among conservationists for having one of the world's largest protected areas co-managed by indigenous people. The 3.4×10^6ha Kaa-Iya del Gran Chaco National Park, on the border with Paraguay, is administered by the *Capitanía de Alto y Bajo Isosog* representing some 9500 Guarani *Izoceños* in 25 communities. They own >300000ha of adjacent territorial lands, which they use for hunting and resource extraction (Arambiza and Painter, 2006; Figure 4).

Complementary ABS research

One set of complementary ABS research in the Gran Chaco has examined the effectiveness of community institutions for monitoring and managing biodiversity. Research teams at long-term study sites in Paraguay, Argentina, and Bolivia since 1980, focused on community-based biodiversity monitoring and sustainable use of wildlife as a conservation strategy (Fitzgerald *et al.*, 1991, 1994). In the Bolivian Chaco, WCS implemented a program led by Andrew Noss, to train local Izoceño, Ayoreo, and Chiquitano hunters to work as para-biologists who self-monitor wildlife use in their communities and carry out field research on target species (Noss *et al.*, 2005). The local parabiologists and community leaders have taken steps to implement sustainable use of *Tupinambis* lizards, red-footed tortoises, and peccaries. Ecological studies comparing population dynamics of target species and makeup of ecological communities across a spectrum from unregulated use to full protection can be tied to social science research on the ways in which communities govern wildlife use in the Chaco.

Complementary research on the history, drivers, and patterns of land cover change in the three countries may elucidate the role of different development histories and governance regimes on biodiversity in the Gran Chaco. For example, in contrast to the indigenous co-management of conservation areas in Bolivia, the Paraguayan Chaco is characterized by predominantly private landholdings and isolated national parks that are off-limits to locals. Understanding the effects of such differences in governance on land use is critical because, to be successful, biodiversity conservation requires not only locally effective conservation programs but also broad geographic linkages among such programs. The trans-boundary region that encompasses the Kaa-Iya del Gran Chaco and Defensores del Chaco national parks in Bolivia and Paraguay, respectively, provide an ideal opportunity to examine variations and potential complementarities or conflicts among land uses, communities and governance structures.

Conclusion

Solutions to the biodiversity crisis will ultimately come from biological and social scientists working in tandem. The goal of this paper has been to describe an integrative strategy for bringing scholars together from different theoretical and methodological backgrounds to collaborate in the pursuit of biodiversity conservation. Getting people together is only the beginning. The ABS approach is explicitly designed to include local institutions and actors in all stages of the conservation research process, as well as planning for broader impacts from the onset. Capacity building of local collaborators and among students in formal training programs is a natural outcome of the ABS approach. The three-pillar framework for ABS (Figure 1) explicitly includes local collaborations from the outset to help ensure that research is relevant and more likely to be translated into conservation programs.

The ABS approach should function at any scale of conservation, from individual decision making, to local resource management institutions, to regional initiatives, to national policies, to trans-border collaborations. A key to successful scaling of the ABS approach is matching research outcomes from interdisciplinary research themes, in this case, ecological functions and biodiversity, and communities and governance. For example, a biological study of the role of predation in ecosystem function in a mosaic of land uses would be matched with a social science study about traditional ecological knowledge among hunters in transition zones between primary forest and agricultural fields. Researchers with long-standing ties to the region will be able to facilitate application of these findings to management of community or territorial lands adjacent to national parks. At a bigger scale, bio-geographic studies of biodiversity would naturally be matched with national and trans-boundary policy research in order to set conservation priorities over broad regions. The research integration matrix should help identify research needs in these types of scenarios based on the perceived causes and consequences of biodiversity loss at the corresponding scale.

The ABS approach is intended to produce conservation scientists who know how to communicate effectively across disciplinary boundaries, and can make their research applicable to on-the-ground conservation through long-term collaborations. As case studies accumulate across sites and over time, a picture will emerge of what conservation strategies are really working, and which ones may be pertinent to new situations. From a scientific perspective, the ABS approach will shed light on the dynamic feedbacks between ecosystem functions, biodiversity, human communities and governance systems, helping to elucidate how and why these are all interconnected.

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CIENCIA APLICADA EN BIODIVERSIDAD: INTEGRANDO ECOLOGÍA, CULTURA Y GOBERNANCIA PARA LA CONSERVACIÓN EFECTIVA

Lee A. Fitzgerald y Amanda L. Stronza

RESUMEN

Las soluciones para la crisis de biodiversidad serán generadas finalmente a partir del trabajo conjunto de científicos naturales y sociales. Pero la desconexión entre disciplinas, instituciones conservacionistas y la implementación de conocimientos impiden la conservación efectiva. La visión de la Ciencia de Biodiversidad Aplicada (CBA) es lograr la integración entre investigación sobre biodiversidad y la práctica de la conservación. Tres pilares sustentan esta propuesta: 1) investigación biológica y social integrada; 2) colaboración entre disciplinas con instituciones y actores locales que trabajan en conservación; y 3) implementación práctica de teorías sobre conservación. Nuestro programa CBA incluye un programa para estudiantes de doctorado y está enfocado en dos temas de investigación: funciones ecológicas y biodiversidad, y comunidades y gobernabilidad. La matriz integrada de investigación relaciona las causas de la pérdida de biodiversidad con los enfoques de la investigación, siendo una herramienta útil para definir hipótesis integradas y formar equipos interdisciplinarios de investigación. Estudios de casos de Amazonia y el Gran Chaco demuestran cómo implementamos el modelo de CBA en Suramérica. La intención es que el enfoque CBA produzca científicos de la conservación que se comuniquen efectivamente entre disciplinas y sus estudios sean relevantes para los programas en ejecución. El enfoque planteado ayudaría a iluminar cómo y porqué las funciones de los ecosistemas, la biodiversidad, las comunidades humanas y los sistemas de gobernabilidad están interconectadas.

CIÊNCIA APLICADA EM BIODIVERSIDADE: INTEGRANDO ECOLOGIA, CULTURA E GOVERNANCIA PARA A CONSERVAÇÃO EFETIVA

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RESUMO

As soluções para a crise de biodiversidade serão geradas finalmente apartir do trabalho conjunto de cientistas naturais e sociais. Mas a desconexão entre disciplinas, instituições conservacionistas e a implementação de conhecimentos impedem a conservação efetiva. A visão da Ciência de Biodiversidade Aplicada (CBA) é conseguir a integração entre investigação sobre biodiversidade e a prática da conservação. Três pilares sustentam esta proposta: 1) investigação biológica e social integrada; 2) colaboração entre disciplinas com instituições e atores locais que trabalham em conservação; e 3) implementação prática de teorias sobre conservação. Nosso programa CBA inclui um programa para estudantes de doutorado e está focado em dois temas de investigação: funções ecológicas e biodiversidade, e comunidades e governabilidade. A matriz integrada de investigação relaciona as causas da perda de biodiversidade com as abordagens da investigação, sendo uma ferramenta útil para definir hipóteses integradas e formar equipes interdisciplinárias de investigação. Estudos de casos da Amazônia e o Gran Chaco demonstram como implementamos o modelo de CBA na América do sul. A intenção é de que a abordagem CBA gere cientistas da conservação que se comuniquem efetivamente entre disciplinas e seus estudos sejam relevantes para os programas em execução. A abordagem sugerida ajudaria a iluminar como e porquê as funções dos ecossistemas, a biodiversidade, as comunidades humanas e os sistemas de governabilidade estão interconectadas.