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Essay

A Role for Natural Resource Social Science in Biodiversity Risk Assessment

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Biologists have made considerable progress in developing realistic simulation models to predict extinction risks for threatened species. Social scientists have to date had a more limited role in these efforts. This limited involvement comes despite the growing acknowledgment by population biologists and simulation modelers that this additional input is necessary for these models to accurately reflect the impact of humans and human-dominated landscapes on wildlife populations. We argue that collaborations among social and biological scientists can provide unparalleled opportunities to develop new conceptual and simulation tools for biodiversity risk assessment. One challenge is that while the value of interdisciplinary research is widely recognized, interdisciplinary teamwork is difficult to achieve. We suggest strategies to strengthen such cross-disciplinary collaboration, including efforts to link diverse models and to

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build networks of researchers who have not historically collaborated. We conclude with questions intended to guide further discussions about how to integrate social science information into biodiversity risk assessments in the future.

Keywords biocomplexity, interdisciplinary collaboration, population viability analysis

Biodiversity Risk Assessment and Social Science

Biologists have made considerable progress in developing realistic simulation models to predict extinction risks for threatened species (Brook et al. 2000; Lindenmayer et al. 2000). Social scientists concerned with natural resource use have to date had a limited role in these efforts. This limited involvement comes despite the growing acknowledgment by population biologists and simulation modelers that this additional input is necessary for these models to accurately reflect the impact of humans and human-dominated landscapes on these wildlife populations (Lacy and Miller 2002). In this essay, we argue that social scientists concerned with natural resource use can—and should—play a larger role in developing new conceptual and simulation tools for biodiversity risk assessment.

Population Viability Analysis

Population viability analysis (PVA), based on computer simulation models, is widely used to predict the likely future status of wildlife populations of conservation concern and to compare alternative management options (Brook et al. 2000; Morris et al. 1999). These models generally examine the effects of deterministic processes (e.g., reproductive rates, mortality, habitat limitations and fragmentation) and stochastic processes (e.g., demographic instability, genetic instability, fluctuating habitat quality) on wildlife populations (Lacy 1993; Miller and Lacy 1999). These processes—many of which vary randomly over space and time in intensity—act synergistically to shape the growth dynamics of wildlife populations (Boyce 1992; Gilpin and Soulé 1986; Lacy 1993; Shaffer 1981; Soulé 1987). Recent tests of these models have shown that, when population-level field data are available, they can represent even complex biological systems (Lindenmayer et al. 2000) and can make accurate predictions of protected wildlife population trajectories over time (Brook et al. 1999; 2000).

In its most applied form, PVA has emerged over time as one of the most effective processes by which human-mediated threats to wildlife populations and habitats are identified and prioritized, alternative management options are defined and evaluated in relation to their effectiveness in promoting demographic stability within declining populations, and strategies for long-term conservation are developed and made operational (Lacy 1993/1994; Reed et al. 2002). As such, PVA is playing an increasingly central role in the formulation of long-term recovery plans for threatened and endangered species worldwide.

However, the ability to incorporate more complex interactions involving social science data and processes into these assessments is more limited. Almost all of the existing models make simplified assumptions about the impacts of human activities on the dynamics of wildlife populations and the ultimate driving forces that affect the proximate threats (Lacy and Miller 2002). If PVA is to evolve into an ever more useful tool, the analytical models we use must be able to more effectively integrate a variety of data types from diverse scientific disciplines. In this way, a more focused picture of the complex nature of human–wildlife interaction will emerge.

Social science data have infrequently been used effectively to simulate the effects of direct or indirect human impacts on wildlife populations and ecosystems for several reasons. First, models are often not designed to incorporate social science data. The wildlife biologists who develop and use PVA models are generally not sufficiently aware of the social sciences to unilaterally incorporate available knowledge about human systems into projections of the impacts of those systems on wildlife. Second, historically biodiversity risk assessment and species conservation has not been an area of research for social scientists interested in modeling, such as social demographers. Where human dimension data have been included, they are often based on broad assumptions or limited empirical data. For example, human demographic models exist to project macro-demographic patterns (McDevitt 1998; Stover and Kirmeyer 1997), but the extension of these projections to include the quantification of a variety of activities by population subsets (e.g., young males ages 15–19 years) and their effects on specific wildlife populations is considerably more challenging (Ness 1997; Vanclay 1998). Moreover, examples of analyses of the impacts of governmental policies, property rights, economic policies, and human value systems on biodiversity, ecosystems, and harvested species have been described (Perrings et al. 1995a; 1995b) but linkages to wildlife population processes have been less well specified. Economic valuations are already widely incorporated into restoration and conservation projects (Carpenter and Turner 2000), but their value has been criticized because of their simplified assumptions (Ludwig 2000).

This is not to say that prior studies have not successfully merged social science with biological models. For example, Radeloff et al. (2000) have used census data to predict land cover, and Mladenoff et al. (1995) have linked wolf-pack territory with transportation corridors and human infrastructure. But these are exceptions rather than the norm in most wildlife population viability applications.

The ideas in this essay evolved out of a 3-year effort under the aegis of the Canadian Social Science and Humanities Research Council. The project, entitled *Social and Scientific Challenges to Biodiversity Conservation*, brought together a group of social and biological scientists to strengthen the inclusion of the human dimension into population viability analyses. This research network has been expanded through a 2-year grant from the U.S. National Science Foundation's Biocomplexity initiative and now includes management and organizational scientists, demographers, population biologists, simulation modelers, and other social and biological scientists. The network has made some progress in developing and strengthening tools and processes to expand the power of simulation models for wildlife risk assessment. Significant outputs include an integrated conceptual framework and conceptual models illustrating how complex human-mediated processes influence specific biological systems and processes (Figure 1) (Scheffer et al. 2000; Westley and Miller in review) and potential tools and processes to gather, translate, and incorporate these complex data into existing simulation models (Lacy and Miller 2002). The network has recently used this conceptual framework and application of existing models of wildlife population dynamics to assess and guide conservation strategies for mountain gorillas in Uganda, Rwanda, and Congo (Werikhe et al. 1998), tree kangaroos in Papua New Guinea (Bonaccorso et al. 1999), and grizzly bears in the Canadian Rockies (Herrero et al. 2000).

As a more detailed example of the approach we have taken, our work in New Guinea revealed that nearly all populations of the six species of tree kangaroos

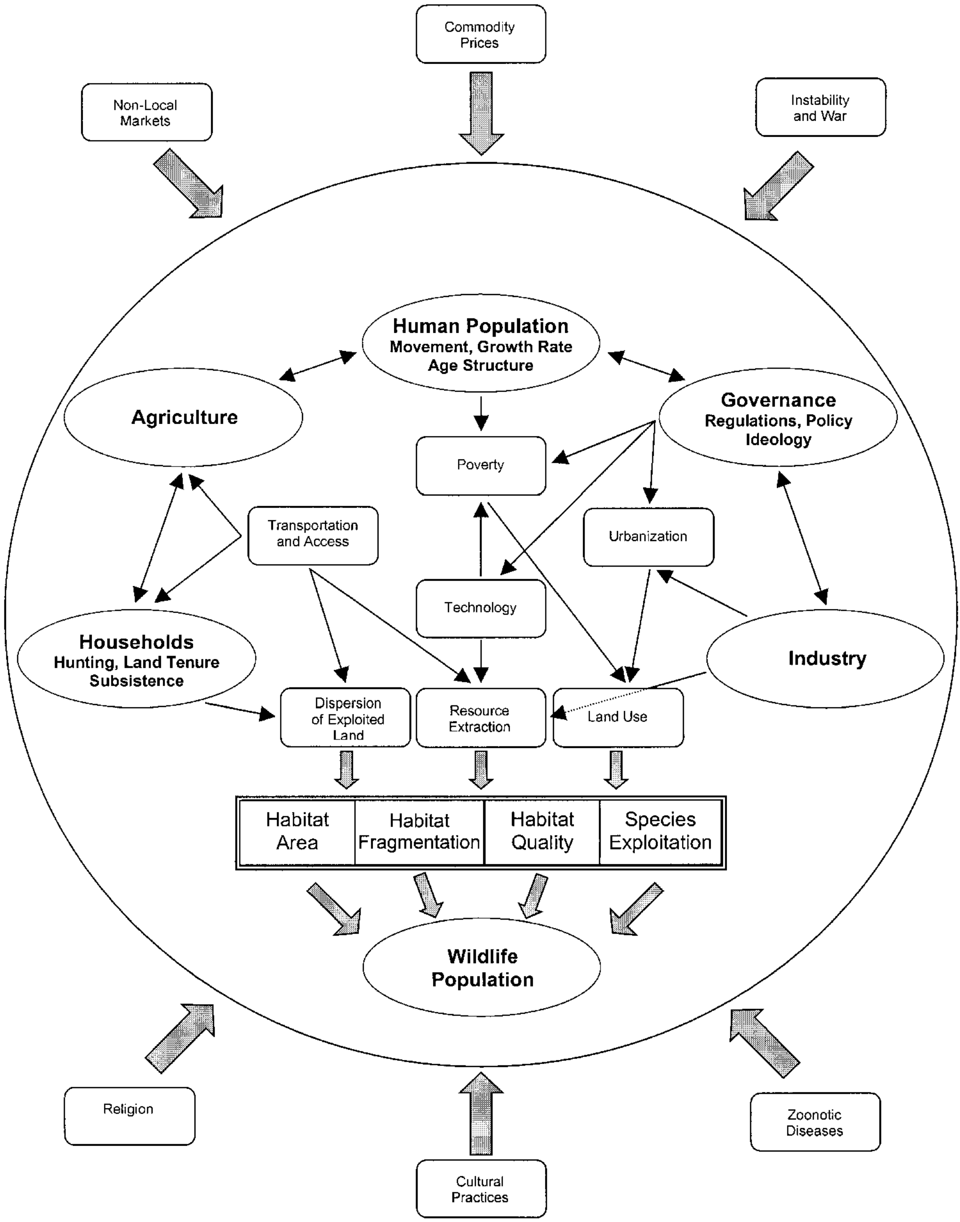

FIGURE 1 Selected human systems that can impact the viability of wildlife populations. Arrows indicate only some possible connections. Not all of the human systems and connections shown here will affect any given wildlife population, and other human activities will be equally important.

(*Dendrolagus* sp.) on the island have declined over the past few decades, and habitat loss continues to accelerate (Bonaccorso et al., 1999). As 96% of the land in the country —and the wildlife on it—is privately owned, the success of our conservation assessment workshop was critically dependent on participation by local landowners.

The information most crucial to an expanded PVA process was not available in the traditional journal format, but existed only in verbal form among the local communities. Our research network put together a team of human demographers and social scientists to conduct detailed interviews, both before and during the workshop, with nearly a dozen landowners from across the country (Nyhus et al. in review). The data from these interviews were used to generate estimates of the village and household size, numbers of hunters per village, and tree kangaroo hunting effort and success. The team then attempted to determine an overall annual rate of removal of tree kangaroos from local habitats, which could then be added to our estimates of "baseline" mortality to assess the direct impacts of human hunting on tree kangaroo population viability.

Additionally, the workshop on grizzly bears of the Central Rockies Ecosystem in Canada revealed that most of the recent mortality of bears in the region is due to humans, primarily legal hunting, illegal hunting, "self-defense" killing by hunters, and animal control deaths by park authorities of problem bears frequently wandering into areas of human habitation or recreation (Herrero et al. 2000). Extensive GIS data exist for this region, including spatial distributions of human land use patterns such as mean road density. Since data on bear demographics and habitat use have been collected over the past 25 years by the Eastern Slopes Grizzly Bear Project (EGBP 1998), a significant opportunity presented itself for a productive synthesis of these two sets of information that had not been previously attempted. During the course of the workshop, a team of participants developed an algorithm for using GIS and animal telemetry data to predict grizzly bear mortality risk as a function of selected map variables. Logistic regression techniques similar to those described in Mace et al. (1999) were used to derive an expression for the relative probability that an animal would die in a specific area defined by a collection of map features, namely, elevation, political jurisdiction, and mean road density. Preliminary mortality risk analyses indicate that (1) the highest probability of grizzly bear mortality in British Columbia and Alberta occurs at lower elevations and (2) mortality overall is greatest at low elevations and high mean road density. These results demonstrated the power of combining GIS and demographic data to derive functional relationships between the spatial characteristics of a given habitat, use of the habitat by humans, and the population dynamics of wildlife using that habitat.

In most of our initial efforts, information about human activities was available only in rather general and qualitative form. The heuristic models of human–wildlife population interactions were in place for each of these risk assessment processes, but methods to translate and incorporate data on human population dynamics, governance, land-use patterns, and other socioeconomic data into perturbations in the demography and ecology of the wildlife population under consideration were not available. Improved methods to translate and incorporate these social science processes are needed to enable more precise modeling of the human activities which most significantly impact wildlife population dynamics—an activity that requires the active collaboration of social and biological scientists.

Integrating Natural Resource Social Science into Biodiversity Risk Assessment

The value of interdisciplinary research and the need to find an integration between the social and the biological or natural sciences to address the concerns of the environment is widely recognized (Heberlein 1988; Pickett et al. 1999; Wilson 1998).

It is also clear that solutions to complex problems such as wildlife risk assessment require the integration of both biological and sociological data and an understanding of human social processes (Clark and Wallace 1998; Lacy and Miller 2002; Machlis 1998; Redman 1999; Wear 1999). This awareness has been recognized in a broad range of interdisciplinary fields from human ecology (Burch 1988) to conservation biology (Soulé 1986), but hurdles to carrying out interdisciplinary discourse remain.

It is less clear how this integration can occur because of disciplinary differences in data types, issues of temporal and spatial scale, and the degree of accuracy required by different disciplines and models. While we know, for example, that human population growth or industrial development endangers species and their habitat, our ability to describe the nature and severity of the impacts of these processes as input into wildlife risk assessment models is limited. While a large number of human social systems and processes will directly or indirectly impact other species, progress toward integrating sociological knowledge into biological risk assessments might initially be made by focusing on a few important linked systems. Such efforts could help to identify methods for integrating disciplinary knowledge, while also helping to solve some very real and complex problems.

Such interdisciplinary teamwork is difficult to achieve because as a society of specialists, we have a low level of interaction. As Heberlein (1988) observes, barriers to joint involvement between social and natural resource scientists include the limitations of social science theory, data, methods, and traditions; the perceived illegitimacy of the social sciences; punishments for interdisciplinary research; lack of disciplinary support structure; issues of power and control, such as research agendas that are set by people who are not social scientists; and problems linking natural science and social science models. The departmental structure at most universities and a tenure and reward system based on review by peers within one's discipline may contribute to some of the problems. Communication barriers among disciplines are also an obstacle. It is widely recognized that interorganizational collaboration is essential for resolving "domain" problems (MacNeill et al. 1991; Trist 1983), but our understanding of what processes result in successful collaborations is much less clear (Gray 1989; Westley and Vredenburg 1996).

To change this involves the commitment of senior people in the field, funding and publication outlets, and the arduous process of building transdisciplinary communication and trust (Daily and Ehrlich 1999), processes that are time-consuming and require patience. Commitment to this process will vary, and bringing on new people after the process has started is a challenge (Naiman 1999). One difficulty is the fundamental difference in discourse and dialects among disciplines, requiring a period of translation and mutual learning (Wear 1999). This transition is demarcated by stages and phases each with its own dynamic, from "problem definition/recognition" in which a statement of the problem or problems under consideration needs to be crafted so that all the involved disciplines can relate it to their base of knowledge, to defining direction, which at the interdisciplinary level is often a problem of methodology (Pickett et al. 1999). Issues of dominance and power are critical. If more powerful or influential disciplines "highjack" this process, the less powerful will become disaffected and be prone to withdraw (Gray 1989). Mutual trust and commitment are fragile developments, easily reversed. However, concrete experiences (field trips, simulations, a concrete research site) can provide shortcuts (Pickett et al. 1999). The use of analogy and sustained metaphor can help to build bridges (e.g., the comparison between ecological patch and neighborhood) (Grove and Burch 1997) as can the choice of "middle level perspectives/phenomena" whether theories (Pickett et al. 1999) or foci, such as a species or a habitat. The critical role of "social interaction and long-term associations that allow friendships to develop" (Daily and Ehrlich 1999) cannot be underestimated. This is the glue that allows the collaboration to hang together through frustrations, and ultimately allows constructive conflict to surface. These conflicts are critical if transdisciplinary effort is to become interdisciplinary and if the problem resolution is to be reached. Finally, institutional support and funding for interdisciplinary research can enhance the likelihood of interdisciplinary collaboration (Heberlein 1988).

Several research areas in particular that could value from such cross-disciplinary linkages include efforts to incorporate the effects of roads (Forman and Alexander 1998; Trombulak and Frissell 2000), pollution (Carpenter et al. 1998;1999), harvesting of plant and animal species (Clayton et al. 1997; Coomes and Barham 1997; Ludwig et al. 1997; Robinson and Bennett 2000; Woodroffe and Ginsberg 1998), and indirect human impacts, including political instability and war (Plumptre et al. 1997); or changing industry strategies and practices with respect to resources and the environment (Sharma et al. 1999; Vredenburg and Westley 1997; 2001; Westley and Miller in review) on endangered species viability and management.

We believe collaborations among social and biological scientists can provide unparalleled opportunities for creative synthesis of diverse methodologies. Three strategies in particular could strengthen these cross-disciplinary efforts. First, there is a need to further develop models that simulate the interactions connecting people, landscapes, and species. Second, there is a need to integrate existing models and conceptual tools in new ways to develop a better predictive understanding of biodiversity risk assessment. Third, there is a need to build networks of researchers (including natural resource social scientists) who may not have historically collaborated to develop new research approaches in biodiversity risk assessment. A forum is needed to integrate modeling tools; integrate expertise; include individuals, methods, and institutions that might otherwise not collaborate; and examine and monitor the implications of this integration for future research. These activities need to take a holistic approach to integrate processes and data across disciplinary boundaries, spatial scales (patch, ecosystem, continent), and species.

We hope this essay will encourage further dialogue on how these activities can be accomplished. We offer the following questions to guide further discussions related to integrating social science information into biodiversity risk assessments in the future.

1. How can we bridge the linguistic, data, and heuristic divide to stimulate the incorporation of social science data into biodiversity risk assessments?
2. How can we incorporate qualitative social science data (e.g., from rapid or participatory rural appraisals) into quantitative population and habitat viability assessments?
3. Can we utilize capabilities in modeling software to specify social system drivers of the biological systems that determine the fates of species and habitats?
4. How can we use the outputs from these biological models as driving forces or feedbacks in models of human systems?

5. How can we organize for long-term successful collaboration among social and biological scientists in determining biodiversity risk assessments and management of endangered species?

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