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Conserving Mangrove Ecosystems in the Philippines: Transcending Disciplinary and Institutional Borders

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Abstract Humans are rapidly depleting critical ecosystems and the life support functions they provide, increasing the urgency of developing effective conservation tools. Using a case study of the conversion of mangrove ecosystems to shrimp aquaculture, this article describes an effort to develop a transdisciplinary, transinstitutional approach to conservation that simultaneously trains future generations of environmental problem solvers. We worked in close collaboration with academics, non-government organizations, local government and local communities to organize a workshop in Puerto Princesa, Palawan, Philippines. The primary objectives of the workshop were to: (1) train participants in the basic principles of ecological economics and its goals of sustainable scale, just distribution and efficient allocation; (2) learn from local community stakeholders and participating scientists about the problems surrounding conversion of mangrove ecosystems to shrimp aquaculture; (3) draw on the skills and knowledge of all participants to develop potential solutions to the problem; and (4) communicate results to those with the power and authority to act on them. We found that the economic and ecological benefits of intact mangroves outweigh the returns to aquaculture. Perversely, however, private property rights to mangrove ecosystems favor inefficient, unjust and unsustainable allocation of the resource—a tragedy of the non-commons. We presented the workshop results to the press and local government, which shut down the aquaculture ponds to conserve the threatened ecosystem. Effective communication to appropriate audiences was essential for transforming research into action. Our approach is promising and can be readily applied to conservation research and advocacy projects worldwide, but should be improved through adaptive management—practitioners must continually build on those elements that work and discard or improve those that fail.

Keywords Ecological economics · Aquaculture · Mangroves · Ecosystem services · Post normal science · Conservation · Transdisciplinary

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Introduction

Ecosystems contribute to human welfare in two fundamental ways. First, the structural building blocks of ecosystems—plants, animals, minerals, soils, land, water and so on—provide the raw materials for all economic production. Second, ecosystems provide life support functions as well as other valuable services, many of which are essential to human welfare and for all practical purposes, non-substitutable. Unfortunately, there is a clash between these two roles, as removal of structure and the return of waste into the ecosystem degrade function, including the ability of ecosystems to renew themselves and to recover from exogenous shocks. Human society must therefore strike an appropriate balance between conversion and conservation of ecosystems (Costanza and others 1991;

Daly 1996). Many scientists fear that continued conversion and waste emissions threaten irreversible and catastrophic declines in critical ecosystems in the near future, with global repercussions (Catton 1982; Wackernagel and others 2002; Wilson 2002; IPCC 2007). Their concerns may be swaying both policy makers and the public towards action. However, the problem of conservation is highly ("wickedly") complex, involving interactions between natural systems, social systems, and human values across temporal and spatial scales (Ascher 2001; Ludwig 2001; Berkes 2004). We need not only the willingness to conserve ecosystems, but also the knowledge of how to do so, in addition to the ability to turn that knowledge into action.

This article describes an approach to conservation that integrates research, training, advocacy and action, using a case study of its application to the conversion of mangrove ecosystems to aquaculture in Ulugan Bay in the Philippines. We designed our approach to overcome a number of significant obstacles to conservation.

First, conservation is a multi-faceted problem that cuts across conventional academic disciplines. Humans are an integral part of ecosystems, and societies have co-evolved with them (Gowdy 1994; Norgaard 1994). Understanding the social-ecological system requires synthesis across the social and natural sciences (Funtowicz and Ravetz 1994; Berkes and Folke 1998; Kinzig 2001), leading to strong calls for interdisciplinary research in the conservation science literature (Brewer 2001; Ewel 2001; Czech 2002; Mascia and others 2003; Sánchez-Azofeifa and others 2005). Unfortunately, analysis of textbooks and syllabuses in conservation science shows little evidence of interdisciplinary training (Niesenbaum and Lewis 2003), and interdisciplinary research continues to confront serious obstacles in academia (Campbell 2005). Effective solutions demand that we transcend disciplinary boundaries.

Second, conservation affects and is affected by different sectors and institutions in society in different ways. Viable conservation strategies require an integrated effort from scientists, conservation professionals, community stakeholders, governments, non-governmental organizations and the business sector (Farley and others 2005). Unfortunately, conservation scientists have largely failed to integrate their scientific knowledge into specific social, political and economic contexts so that it actually leads to conservation (Bawa and others 2004). The recent Millennium Ecosystem Assessment report (2005), conservation groups and academics are all calling for inter-institutional collaboration (Farnsworth 2004). Effective solutions demand that we transcend institutional boundaries.

Third, we must recognize that in the field of conservation, facts are often uncertain, decisions are urgent, stakes are high, values are disputed, and the relevant sample size may be one unique system. Under such conditions, there can be no objective decision-making rule and the conventional scientific method alone is inadequate. Effective solutions demand that we move beyond the boundaries of the conventional scientific method (Funtowicz and Ravetz 1993; Ludwig 2001; Farley and others 2005).

Finally, we must learn effective communication in order to transcend the boundaries between research and action. Scientists must learn effective communication across disciplines, as well as with various stakeholders, decision makers and the broader public (Farnsworth and Ellison 1997; Allen and others 2001; Costanza 2001; Weber and Word 2001; Farley and others 2005, 2007b). While many academics have mastered this task, public communication skills are rarely part of the scientific curriculum. Furthermore, many scientists have difficulty accepting that the political process is typically influenced more by storytelling and the strategic interpretation of scientific research than by data and cold, hard facts (Stone 2002). Even with such acceptance, they often consider strategic interpretation as too subjective and outside the realm of scientific endeavors (Lackey 2001; Wagner 2001). However, if scientists hope to solve the conservation problem, and objective scientific research tells us that compelling stories influence policy makers more than dry facts, then problem-solving scientists must tell those stories (Farley and Miles 2008).

We attempted to address all of these obstacles to conservation in a transdisciplinary workshop/field-course in ecological economics funded by the John D. and Catherine T. MacArthur Foundation that took place in Palawan, the Philippines, January 2–16, 2003. The immediate objectives of the workshop were to learn from local non-governmental organizations (NGOs) and communities about the problems presented by the conversion of mangrove ecosystems to shrimp and fish aquaculture, train participants to apply the principles of ecological economics to help solve them, and communicate results to decision makers. Our broader goal, pursued across several different workshops around the world, was to develop a framework for conservation efforts and education that: (1) transcends disciplinary and institutional boundaries; (2) adopts the approaches of post-normal science (described below); and (3) stresses communication across disciplines, institutions and geographical regions, in order to (4) translate academic and local knowledge and community goals into effective conservation projects. Although we believe this approach is necessary for solving complex problems and for training people to solve them, we realize it is not sufficient. Our framework led to some success in this specific case study, but we also recognize several shortcomings that we describe in our conclusions.

The first section of this article introduces the problem of mangrove conversion and conservation and describes our study site. The second section presents our methods. The third and fourth sections present and discuss results. We then explain how we communicated our results to decision makers and the public. We conclude with reflections on the strengths and weaknesses of our approach, its applicability to conservation issues elsewhere, and suggestions for future research.

The Problem of Mangrove Conversion

The Ramsar convention on wetlands defines mangrove forests as a community of "taxonomically diverse, salt-tolerant tree and other plant species which thrive in intertidal zones of sheltered tropical shores, 'overwash' islands, and estuaries" (Quarto 1997, p. 1). Specially adapted to saline wetlands hostile to other plant life, mangrove trees have aerial, salt-filtering roots capable of providing oxygen in anoxic conditions, and salt-excreting leaves, among other attributes. Humans also favor coastal zones for settlement, recreation, and economic activities, and, unfortunately, are often in direct competition with mangroves (Alongi 2002). Healthy mangrove ecosystems provide an abundance of goods and services of critical importance to humans and other species, examples of which are offered in Table 1. In contrast to human made capital, these benefits are provided in perpetuity with no depreciation or maintenance costs, continually renewed by solar energy. The interaction between human society and mangrove ecosystems offers an excellent case study of a complex problem best addressed through a transdisciplinary participatory problem-solving approach.

In spite of the benefits they provide, mangrove ecosystems are being lost at an alarming rate around the world. Once covering some three quarters of tropical coastlines (Farnsworth and Ellison 1997), conversion to aquaculture, pollution, extraction, and coastal development have wiped out an estimated 1/3 of mangrove forests (Alongi 2002) over the past 50 years and at least ½ (GESAMP 2001) over the last century, with much of the loss occurring in the last two decades. Many of the remaining mangroves are in degraded condition; Alongi's estimate includes regrowth and reforestation, often with fewer species and reduced function. In the Philippines, of the 400,000 ha of mangroves recorded in 1918, scarcely ¼ still remain (Primavera 2000), and much of the remainder is degraded or restored forest that provides fewer ecosystem services (Walters 2003).

The leading cause of mangrove loss is conversion to shrimp and fish aquaculture (GESAMP 2001; Alongi 2002; Primavera 2006) in which coastal mangrove forests are cleared for ponds, seeded with shrimp larvae and/or juvenile fish, and provided with fish meal feed in order to grow shrimp and fish to adult size at high densities. Aquaculture pollutes local waters with effluents, spreads disease, and by pumping vast amounts of fresh groundwater, often draws saltwater into coastal aquifers, damaging the water supply of local communities. Following three to ten years of production, intensive shrimp aquaculture operations typically succumb to disease, pollution and other problems, and are then abandoned (de la Torre and Barnhizer 2003). Ironically, shrimp aquaculture depends heavily on the ecosystem services provided by healthy mangroves (Kautsky and others 2000). As aquaculture depletes the ecosystems that sustain it, it moves on to new locations in a case of 'roving banditry' (Ellison 2008). For example, Ecuador, a global leader in aquaculture shrimp production during the 1980s, saw its industry collapse in the 1990s after mangrove clearing depleted post larval shrimp stocks used for stocking its ponds (Parks and Bonifaz 1994) and diseases broke out in the ponds (Kautsky and others 2000).

As a result, conversion of mangroves to aquaculture has become highly controversial. For investors, the international demand for shrimp in particular makes aquaculture a lucrative opportunity despite declines in shrimp prices over recent decades. For developing nations, shrimp aquaculture brings in export earnings and foreign exchange. Yet coastal communities in over 40 nations have come into sharp conflict with the shrimp aquaculture industry as wild fisheries and other ecosystem goods and services have declined and reduced the incomes of coastal communities as a result of shrimp aquaculture expansion (de la Torre and Barnhizer 2003).

Our project focused on community conflict with mixed shrimp and fish aquaculture in Ulugan Bay, in the municipality of Puerto Princesa, Palawan, the Philippines (see Fig. 1). Ulugan Bay accounts for 15% of all mangrove forests in the Philippines. It also contains extensive coral reefs and sea grass beds (UNESCO 2002). We describe here our work with Barangay Tagabinet (see Fig. 1), a low-income fishing and farming community with a 1998 population of 864 (Felstead 2001). A group of outsiders (whose exact identity was difficult to ascertain) had recently re-established and begun expanding a previously abandoned 10-hectare aquaculture project in the mangroves bordering Tagabinet. The mangrove forest in question was otherwise intact, though most mangroves in the Philippines have been altered by humans (Walters 2003). In fact, relatively small tree size indicated that trees were cut for local household use (UNESCO 2002). The forest is near the St. Paul Underground River National Park, a World Heritage Site boasting one of the best preserved ecosystems on one of the Philippines' best preserved islands.

Methods

Our approach to applied problem solving operates on the principle that the problem determines the specific

Table 1 Examples of ecosystem goods and services provided by mangroves (adapted from Costanza and others 1997; de la Torre and Barnhizer 2003; Moberg and Ronnback 2003)

Ecosystem service	Provision by mangrove ecosystems
Gas regulation	CO_2 storage. Growing mangroves create O_2 and absorb CO_2 and SO_2
Climate regulation	*Global climate* can sequester up to 1.5 tons of carbon/ha/year (Ong 1993); *Regional climate*: evapotranspiration and cloud formation affect both rainfall and transport of stored heat energy to other regions by wind; *Microclimate*: shade and insulation affect local humidity and temperature extremes
Disturbance regulation	Buffer adjacent terrestrial communities and ecosystems against storms and tsunamis. Slow the rate of water flow and allow silt to settle out, reducing the impact of flooding on adjacent marine ecosystems such as sea grass beds and coral reefs
Supply of raw materials	Building materials (durable, water resistant timber and thatch); energy (charcoal and firewood); food resources (crabs, mangrove worms, fish, honey, sugar, fruits, alcohol, vinegar, animal fodder); traditional medicines; fur; aquarium industry products; tannins; dyes from bark; lime; etc.
Water supply	Evapotranspiration can increase local rainfall, also involved in water catchment and groundwater recharge
Waste absorption capacity	Capture and absorb large amounts of waste flowing from land, including nutrients and industrial waste, protecting marine habitats
Erosion control & sediment retention	Stabilize land against the erosive forces of the sea, slow water flow allowing sediments and pollutants flowing from land to settle
Nutrient cycling	Capture and reuse nutrients that might otherwise pollute marine ecosystems; remineralize organic and inorganic matter; export organic matter to other ecosystems
Pollination	Provide habitat and food for insects and bats, thus helping support the wild populations of these highly valuable pollinators
Biological control	Provide habitat and food for insect bat and bird species that prey pest species
Refugia or habitat	Provide vital habitat and create conditions essential to reproduction for a wide range of terrestrial and aquatic species. Support a vast variety of marine life in complicated food webs supported by the detritus they generate. Estimates of commercial seafood species that depend on mangroves for at least some stage of their life cycle range from 67% in eastern Australia (Untawale 1986) to 80% in Florida (Hamilton and Snedaker 1984), and nearly 100% of the shrimp catch in ASEAN countries (Singh and others 1994; all cited in Ronnback 1999). Provide habitat for indigenous people
Genetic resources	Contain unique biological materials, many of which have medicinal uses
Recreation	Boating, birdwatching, fishing, etc.
Cultural	Aesthetic, artistic, educational, spiritual and scientific values

appropriate theories and methods to apply. There is no generic blueprint for all conservation projects. To understand the problem of mangrove conversion and seek effective solutions, we developed an applied, problem-solving workshop/field-course that blended elements of a "scientific atelier" with an ecological economic "skill-share".

The scientific atelier is a self-designing, collaborative problem-solving process pioneered by the Gund Institute for Ecological Economics (GIEE). This approach brings students and faculty from several disciplines together in problem-focused, adaptive, workshop settings. The courses focus on a particular research topic chosen in close collaboration with a community partner. Atelier organizers assemble myriad resources demanded by the specific problem. The approach assumes "peer-to-peer" interactions among the participants, and 'upstream' synthesis of knowledge from various disciplines before results are turned over to decisions makers and other knowledge users (Kinzig 2001). Concrete outputs typically include academic journal articles and other publications with practical policy implications.

The ecological economic skill-share is a similar process developed by Earth Economics in which ecological economists learn from activist organizations and community groups about the issues they tackle, educate the activist organizations on the principles of ecological economics, then work together to apply principles to practice in order to solve specific problems. To a greater extent than the atelier, the skill-share addresses problems identified by the local community, stresses local community and stakeholder participation (including academia, NGOs, business and government), and emphasizes implementation of solutions over publications. Synthesis is transinstitutional as well as transdisciplinary. Adding to both approaches, our workshop integrated a web-based teaching module to provide participants with essential background information (http://www.uvm.edu/giee/ateliers/philippines-03/Philippines.html).

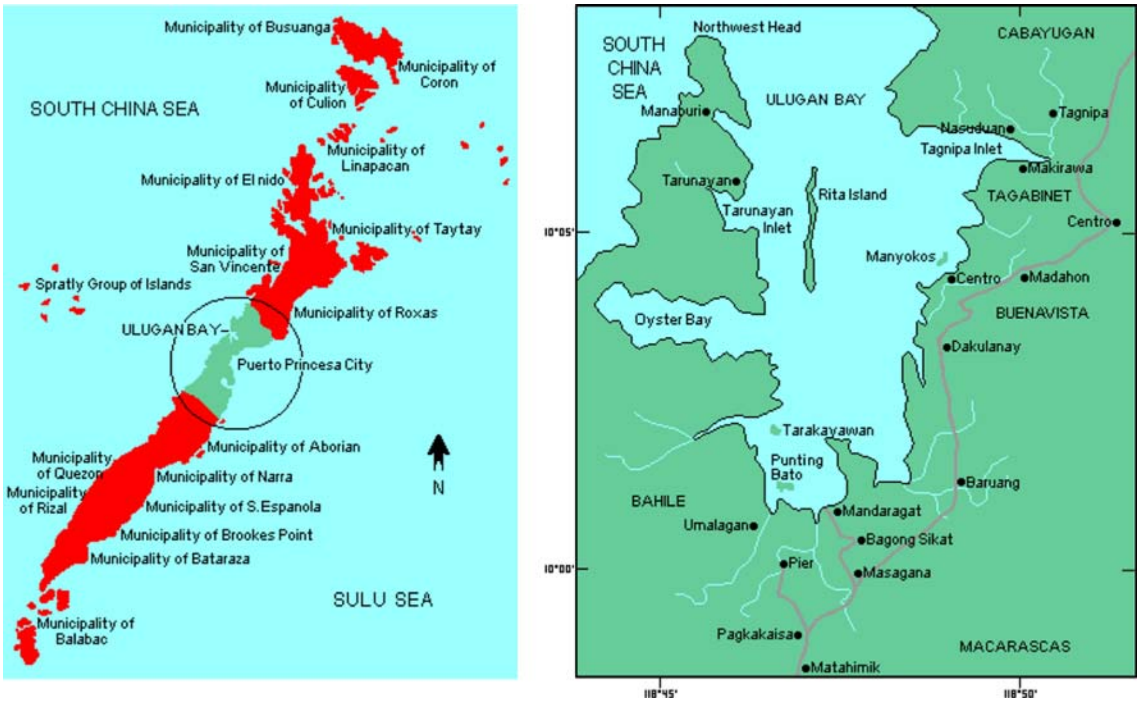

Fig. 1 Palawan Island, The Philippines, showing the city of Puerto Princesa and a blow-up of the Ulugan Bay region, showing Tagabinet (UNESCO 2002)

An interdisciplinary group of university professors from the University of Vermont's GIEE and two international NGOs—the Asia Pacific Environmental Exchange (APEX) and the Industrial Shrimp Action Network (ISANet)—initiated the atelier/skill-share, choosing as a general topic the impact of shrimp and fish aquaculture on mangrove ecosystems, fisheries, and local communities in South-East Asia. APEX and ISANet used their extensive contacts in the Philippines to arrange partnerships with national and local NGOs: the Philippines Rural Reconstruction Movement (PRRM, one of the oldest NGOs in the Philippines), the Environmental Legal Assistance Center (ELAC), and Tambuyog (a Filipino NGO working on fisheries issues). These partners identified the island of Palawan in the Philippines as an appropriate site for the workshop. The City of Puerto Princesa under Mayor Edward Hagedorn and the Palawan State Technical College also joined as organizers, co-sponsors and participants. ELAC identified the communities of Tagabinet and Babuyan, where it was already working, as appropriate case studies.

For the problems we chose, the conventional scientific method was inadequate. Firstly, facts were highly uncertain as we knew of no baseline data concerning the specific mangrove ecosystem or the Tagabinet community. We also did not know how resilient the mangroves would prove to human activities, the impact of those activities on the provision of ecosystem services, or the time lags involved. It was impossible to predict novel technologies that might substitute for ecosystem services from the mangroves (Faber and others 1998). We had no access to site-specific economic data for the aquaculture ponds. A sample size of one unique and evolving ecological-economic system made statistically significant observations impossible. Decisions were urgent because the mangroves were being cleared as we worked; delaying decisions while we gathered data would have been an irreversible choice. Stakes were also very high—on the local level, Tagabinet risked losing the valuable ecosystem services provided by the mangroves, while at the global level, mangrove forests were in precipitous decline. Finally, values were in dispute as the decision to conserve versus convert the mangroves had different impacts on different groups.

Under these circumstances, we adopted the methods of post-normal science (PNS), which modifies traditional science in four important ways. First, given pervasive uncertainty and conflicting values, it extends the notion of expertise to include the knowledge and values of stakeholders intimately familiar with the system and not limited by disciplinary blinders. Second, it recognizes the value of folk wisdom, local knowledge, anecdotal evidence, investigative journalism and small scale surveys in decision making as well as expert opinion and conventional scientific evidence. Third, it accepts that urgent decisions with high stakes must be made with limited information, and recognizes a cost of acquiring more information is the possibility of irreversible and catastrophic outcomes. Finally, PNS reassesses how to evaluate the quality of a decision. Peer review, analytical rigor and replicability are judged far less important than an open debate among those interested in the outcome (Simon 1983; Funtowicz and Ravetz 1994; Ludwig 2001; Farley and others 2005).

It is important to emphasize that our local partners identified the specific problems, sites and ultimate goals at the local level. Our objective was not to parachute in to study a problem for two weeks, but rather to contribute our skills and resources to ongoing local NGO efforts, thus ensuring solid background preparation, community involvement, and continuity. An equally important objective was to help train participants in the skills needed to address complex problems.

Selected through a competitive process, participants (34 Filipinos, 20 internationals) came from six continents and included students, professors, NGO staff, government officials, and lawyers. Collectively, these participants held expertise in fisheries, economics, ecology, environmental education, ecotourism, hydrology, tropical coastal biology, shrimp aquaculture, ecological restoration, systems modeling, GIS, law, and communication. Organizing the workshop consisted of identifying the primary issues, partners, format, and background information that were made available on the Web. All participants were required to review the web-site to acquire essential background information. ELAC identified project sites and key questions and built local commitment and participation.

Our approach emphasized *analysis* of the component parts of the problems, *synthesis* to understand how the parts interact to form a whole system, and *communication* of the results to each other, decision makers and the broader public (Farley and others 2005). Synthesis of existing information took precedence over primary research. Through effective communication we also intended to make our results useful to other communities and decision-makers in Asia, Africa and Latin America.

Narrative of the Project

Participants began the workshop with a basic training in ecological economics followed by an intensive three-day immersion in the issues. Presentations began from the global perspective, covering the impacts on local people affected by aquaculture around the world; global statistics and patterns of investment and trade in shrimp; the perspectives of the aquaculture industry and government officials; and the social and environmental impacts of shrimp aquaculture in other countries and regions of the Philippines. Site specific presentations addressed the ecology of Palawan's mangroves and the natural and political history of Palawan. The immersion continued with two days of visits in Palawan (hosted by ELAC, Tambuyog and the City of Puerto Princesa) to shrimp and fish aquaculture sites, healthy mangrove forests, local coastal communities, and St. Paul's Underground River National Park, adjacent to Tagabinet. We also met with members of communities affected by aquaculture and listened to their views.

With this foundation, multi-disciplinary and multi-institutional groups formed around specific issues of primary concern to the Tagabinet and Babuyan communities. The initial task of each group was to analyze a particular component of the problem, such as the ecological impacts of conversion and valuation (qualitative and quantitative) of services lost; community attitudes towards conversion; the economic benefits and risks of shrimp aquaculture; the distribution of both economic and ecological costs and benefits; alternative means of earning a livelihood; legal issues; mangrove restoration; and so on. Groups encompassed the full diversity of participants and included group facilitators.

One serious challenge we faced was communication. Most academic participants had been trained in the specialized jargon of their discipline, while different institutions (i.e. academia, NGOs, government, and community members) and nationalities faced cultural barriers to communication. However, transdisciplinary collaboration on a real life problem helped overcome communication barriers. The integration of theory and practice transforms multidisciplinary research into transdisciplinary research (Hanna 2001). Studying a system as a whole also gives everyone a shared understanding of a general problem. Anyone who has learned a foreign language knows that in the beginning, conversation is greatly facilitated when you are familiar with the topic being discussed. You might not understand a specific word, but in context the meaning becomes obvious. Exactly the same principle applied to transdisciplinary integration: a team of conservation scientists from a variety of disciplines can communicate more effectively when they share basic knowledge about the system they are discussing and can explain disciplinary jargon to others through examples drawn from shared knowledge. The same dynamic applies to communication across institutions—applied, problem-based research helps transcend both disciplinary and institutional borders.

Under the circumstances of the project, stakeholder engagement was critical, particularly so in the absence of any objectively 'optimal' outcome. We also believed that the more the stakeholders were involved with the project, the more likely they were to find research results to be credible and act on them. However, we had to be aware that the more involved stakeholders had more to gain or lose from any particular outcome. Information from disinterested stakeholders, therefore, carried considerable weight.

Realizing our limitations as outsiders newly arrived in the region, we partnered with ELAC, in order to use the data it had gathered and take advantage of the social capital it had built with the community. ELAC and our other national partners also facilitated cross-cultural communication with stakeholders. We accepted the consequences of potentially prioritizing the interests of a deeply involved stakeholder, but were still unable to fully integrate community members into the atelier process.

Because clearing of the mangrove and dike construction was taking place as we were studying the problem, threatening the irreversible loss of the ecosystem and the services it provided, there was no time for sophisticated scientific assessments. It was imperative that we come to concrete conclusions during the workshop and somehow implement them. If we failed to transcend the boundaries between research and action, our acquired knowledge would only apply to a system no longer in existence. Adjusting to the urgency of the situation and the uncertain nature of the facts, we relied partly on anecdotal information provided by informal interviews with community members and local workshop partners. We supplemented local knowledge with the results of scientific research on similar systems elsewhere. We strove to gather the minimum information needed, as best we could judge, to assess the situation and propose a course of action. Because stakes were high, we sought to use triangulation wherever possible—when three or more separate sources or disciplinary perspectives agreed, the information carried more weight. We also sought to avoid irreversible outcomes—arguments for inaction had to bear the burden of proof.

Analysis was interspersed with synthesis, which in this case meant examining how the various parts of the ecological economic system fit together in order to suggest policies that would promote a sustainable, just, and efficient use of the mangrove forest. Our approach was for all of the working groups to present their results to each other in the evenings following fieldwork, a daily peer review of results. Experts in systems modeling integrated the results into computer simulations of the ecological economic system that provided a clear picture of the whole system and helped us identify key feedback loops as well as potential places to intervene in the system to produce desirable outcomes.

Results and Discussion

Although we gathered considerable information, we report only on what proved to be most important to the project's outcome. This includes the benefits derived from healthy mangroves as compared to those of shrimp aquaculture, to whom those benefits accrued, the legal status of the deforestation, and the forces driving conversion and its irreversibility. As the nature of the problem forced us to integrate original but often anecdotal research with published scientific literature, we present both here as results of the project.

Healthy mangroves provide both ecosystem goods (raw materials, or elements of ecosystem structure) and ecosystem services (those ecosystem functions of value to humans). Goods in general are transformed through use, can be stockpiled, and harvest rates are decided by the harvesters. Goods harvested by local community members included building materials, 'mangrove worms' (a local delicacy), crabs and fish. Primavera (2000) reports estimated values of forestry products from mangroves ranging from \$10–4,000/ha/year.

In contrast to goods, services are typically not transformed through use, cannot be stockpiled, and are provided at a given rate over time (Georgescu-Roegen 1971; Daly and Farley 2004). Mangroves provide fish indirectly by serving as a nursery for most of the region's commercial fish species, and fishing is one of the main sources of income in Ulugan Bay (Felstead 2001). Mangroves also help sustain fisheries by capturing pollutants and sediments in water runoff and waste emissions from aquaculture, thus protecting coral reefs, sea grass beds and other critical marine habitats (Gilbert and Janssen 1998; Tam and Wong 1999). In the Philippines, 1.7 billion milkfish fry for stocking fishponds are captured annually in the wild destroying an estimated 10 billion fry of other species in the process. Recognizing that aquaculture ponds often have a short life expectancy, foul surrounding ecosystems with their waste, and frequently transmit diseases to wild populations (Primavera 2006), it is quite likely that mangrove ecosystems actually produce more seafood when intact than when converted to shrimp ponds. To make matters worse, shrimp are carnivores, requiring, on average, nearly 3 kilos of fishmeal to produce one kilo of shrimp (Naylor and others 2000).

We found no specific estimates for Ulugan Bay of the value of mangroves in sustaining commercial seafood production, but in rapidly changing non-linear systems we would expect swift change in values anyway. Studies elsewhere have estimated monetary values of mangroves in sustaining commercial seafood production ranging from \$120–3,000 ha^{-1} $year^{-1}$ (Alongi 2002), while Ronnback (1999) reports estimates ranging from \$750–\$11,280 ha^{-1} $year^{-1}$ and \$850–\$16,750 if the value of by-catch is included. Naylor and others (2000) estimate that for every kilo of shrimp harvested from shrimp ponds in Thailand, 447 g are lost from near-shore fisheries alone.

The 2004 tsunami drew considerable attention to the role of mangroves in protecting nearby communities against storms, tsunamis and wave surges (Dahdouh-Guebas and others 2005; Danielsen and others 2005; Barbier and others 2008). The Tagabinet mangroves and the biodiversity they sustain also contributed to the spectacular beauty of the area. A growing ecotourism industry and an initiative to develop community-based sustainable tourism in the region promised to convert this beauty to income (UNESCO 2002).

A small indigenous community on the edge of the Tagabinet mangroves probably depended the most heavily on the goods and services it provided.

In addition to the direct benefits to the Tagabinet community, the mangroves provided regional and global services. Mangroves sequester large amounts of carbon dioxide (Ong 1993; Fujimoto 2000), and provide vital habitat for a number of far-ranging terrestrial and marine species, including many that are threatened (Moberg and Ronnback 2003). Both biodiversity and climate stability are almost certainly critical to the functioning of global ecosystems (Millennium Ecosystem Assessment 2005; Worm and others 2006).

While it is exceptionally difficult to estimate monetary values for non-marketed ecosystem services, and we share serious concerns about the legitimacy of doing so (Vatn and Bromley 1994; Gowdy 1997; Martinez-Alier and others 1998), Costanza and others (1997) reported a mean value for all ecosystem services provided by mangroves of \$9,900 ha^{-1} $year^{-1}$. Using meta analysis, Balmford and others (2002) estimated the net present value of intact mangrove forests as approximately four times greater than shrimp aquaculture ponds. Conversion of the mangroves to aquaculture directly threatened these values.

Even though Philippine laws explicitly prohibit the cutting of mangroves, the Department of Agriculture in the Philippines leases coastal lands at very low rates to private owners who subsequently clear mangroves for aquaculture (Primavera 2000). A government lease for an existing shrimp and fish pond in the mangroves near Tagabinet expired in 1999, and was not renewed. The pond was abandoned until a group from outside the community purchased the pond. In 2002, they began to expand it, illegally clearing 14 hectares of mangroves and constructing large dikes to create ponds, threatening the remaining mangroves by disrupting hydrodynamics. This high intensity aquaculture was profitable, but with a short life expectancy, and only employed a handful of local people (though building the dikes employed more people for a brief period). Shrimp production was exported, while milkfish were sold nationally. So, from a short-term financial perspective, aquaculture seemed desirable.

While intensive aquaculture is often short lived, mangrove destruction endures. We saw a cleared mangrove forest that had failed to recover even after six decades of abandonment, probably due to changed hydrodynamics, salinity, and acidity, as well as low nutrient levels and loss of essential substrates. In many cases, even mangrove restoration efforts show little success—the rate of growth in one restoration plot we visited was so slow that town Mayor Hagedorn referred to it as a "bonsai mangrove forest". Restoration of former shrimp aquaculture sites may be extremely expensive, with estimates up to \$13,750 ha in Thailand (Sathirathai 1997), or altogether impractical. Where restoration is possible, most projects have focused on restoring a limited number of tree species, and have failed to restore other associated species and critical ecosystem functions (Alongi 2002; Walters 2003).

Our task was to explain a puzzling dynamic: Healthy mangrove forests generated a sustainable flow of ecological, social and economic benefits indefinitely, constantly renewed by solar energy. In contrast, conversion to aquaculture was an unsustainable, resource intensive, short term enterprise that sacrificed ecological and social benefits in return for profits from seafood production, yet failed to produce even as much seafood as the intact system. Using data from other case studies and a lot of guesswork, an atelier working group estimated that the aquaculture ponds would generate \$13,000–30,000 ha^{-1} $year^{-1}$ for 3–9 years, while the intact mangroves could generate \$5,000–41,000 ha^{-1} $year^{-1}$ worth of goods and services forever. Even focusing solely on market goods, conversion appeared to produce less than conservation. Why, then, did conversion occur?

A partial explanation is that people are simply ignorant of the full benefits of intact mangroves. As recently as the 1940s, Philippine government documents referred to mangrove forests as unproductive swamps, and such ignorance no doubt persists. Related to this, government policy makers and economists often assume that common property management is less efficient than markets (Armitage 2002). However, a more complete explanation must recognize another dynamic, the inverse of Hardin's (1968) well known tragedy of the commons. Hardin argued that a resource will be over-exploited when use depletes the resource but it is difficult or impossible to prevent beneficiaries from using it. Hardin suggested private property rights or 'mutual coercion mutually agreed upon' as the solution. However, the Tagabinet community appeared to have sustainably used its mangroves for generations without private ownership. Considerable research confirms that communities frequently develop effective common property regimes that protect common pool resources as well or better than private property rights (Berkes 1989; Ostrom 1990). The phrase "tragedy of the commons" is in fact a misnomer, and "tragedy of open access regimes" more appropriate (Bromley 1991). In other words, either private property rights or common property rights should be adequate to prevent the tragedy. The sustainable management of Tagabinet's mangroves in the absence of private property rights is simply an example of an effective common property regime.

What proved most interesting in the case of the Tagabinet mangroves however was that the creation of de facto private property rights actually promoted tragedy. On closer inspection, this dynamic makes perfect sense: If aquaculture ponds were not privately owned, anyone could take the shrimp they produced and conversion to aquaculture would not occur. What matters is the distribution of benefits. The benefits from ecosystem services accrue to the local, regional and global communities. The owners of the Tagabinet aquaculture ponds lived in Manila, and would scarcely notice the loss of these services. Even if healthy mangroves produced more seafood than aquaculture ponds, the seafood produced would be caught by hundreds of fishermen in the nearby coastal communities. In contrast, the returns to shrimp aquaculture were captured entirely by the owner of the ponds. Rational, profit maximizing corporate owners privatized benefits while ignoring social costs. In contrast to the tragedy described by Hardin, shrimp aquaculture is an instance of the tragedy of the non-commons, defined as a situation in which private ownership leads to unsustainable, unjust and inefficient resource allocation (Farley 2009). Adger and Luttrell (2000) report on the same dynamic in Vietnam and Indonesia.

There are two reasons this tragedy of the non-commons emerges in the case of mangroves. First, while it is possible to create private property rights to mangrove forest structure, it is impossible to create such rights to most of the ecosystem services they generate. If benefits created by a resource cannot be owned, they cannot be sold in markets, and profit-maximizing managers ignore them. Conversion to aquaculture proves far more lucrative to the private owner. While it would be possible to assign common property rights to the mangrove forest services, such rights would fundamentally conflict with private property rights to the forest structure. The second reason is that many of the critical resources produced by mangroves are non-rival (i.e., use of the resource does not deplete it, leaving just as much for subsequent use by others). For example, when one individual benefits from the role of the mangrove in protecting against storm surges, it in no way reduces the amount of protection left for another person. Though a fisherman harvesting fish reduces the amount of fish available for another fisherman to harvest, it has no impact on the capacity of the mangrove to serve as a nursery, or to filter water and protect the health of the coral reef. When additional use does not deplete the quantity of a resource or benefits provided, then the resource is not scarce in economic terms: rationing through prices will result in inefficient levels of consumption, and private property rights, even when possible, are inappropriate.

Rather than promoting private property rights for mangroves, we should focus on protecting and improving common property management. Mangrove forests are solar powered—for the most part, their production of ecosystem services does not depend on the labor, capital investments, or entrepreneurial ability of any individual. The ecosystem services from mangroves are naturally distributed more or less equally to all individuals within a spatial range of the service in question. Markets, in contrast, allocate resources to those with the highest demand, as determined by preferences weighted by income. In other words, markets allocate according to the principle of one dollar one vote. Perhaps ecosystem services generated by mangroves should be allocated by means of a participatory democratic process—one person, one vote—rather than a plutocratic (market) process (Farley 2008, 2009).

In other words, it should be up to the broader community, informed by the best available science, to decide on the macro-allocation problem: How much mangrove ecosystem should be conserved to provide non-market ecosystem services vital to the community, and how much should be converted to market uses? Of course, the problem remains of deciding who should be included in the 'broader community.' Perhaps the best approach would be to consider the spatial distribution of ecosystem goods and services provided by the mangroves, and weight community participation by the share of benefits received. As the primary beneficiaries of storm protection, seafood production and so on, the Tagabinet community would have the greatest say over its neighboring mangroves.

Communication and Outcomes

One of the most important tasks of conservation science is to communicate results to those with power and authority in a way that stimulates them to act. In the case of the Tagabinet study, that meant government officials. Here again the NGO partners proved particularly valuable owing to their experience in communicating with governments and media. Once we had satisfactorily synthesized the results of our analyses, our NGO partners arranged for a press conference. Both print and television media were invited on Friday afternoon, a slow time for news. We distributed carefully prepared press releases to accompany the presentations summarizing our findings and stressing the unsustainable, unjust, inefficient and illegal nature of the aquaculture ponds. Following the press conference, we gave a separate presentation to the Mayor, government staff from Palawan Province and Puerto Princesa, staff from the Fisheries and Forestry Bureau, and staff and enforcement officers from the National Department of Environment and Natural Resources.

Our presentations helped convince Mayor Hagedorn that something needed to be done to halt mangrove conversion.

Following our presentations, he sought national government permission to destroy the illegal aquaculture ponds. He then solicited the help of the community in destroying the dikes, and arranged for buses to transport everyone to the site.

Following the official end of the atelier/skillshare, remaining participants accompanied the mayor to Tagabinet, where we again presented our results to the press. The mayor then led some 100 community members, local NGO staff and remaining participants to the aquaculture ponds. Another press conference took place, this time involving representatives of the owners of the aquaculture ponds. The numerous presentations and press conferences dually served to communicate our results and evaluate their quality in an extended peer review, as they offered abundant opportunity for open debate among those affected by the mangrove conversion.

Following the final press conference, the community demolished the newest aquaculture ponds. Functioning ponds were left intact to allow harvest, but those too were drained within a few days. In addition to the dike destruction, Mayor Hagedorn implemented a mangrove restoration and monitoring plan for the City of Puerto Princesa. Five months after the workshop, school children planted 10,000 mangroves in former mangrove habitat, and annual reforestation projects continue. While mangrove restoration rarely achieves the full complement of species and functions of the original forest, restoration projects in the Philippines and elsewhere have shown significant benefits for local communities (Walters 2003; Walton and others 2006; Ronnback and others 2007).

Halting one illegal aquaculture project among thousands, while satisfying, has negligible value by itself. However, the local television station presented a two-hour program chronicling workshop findings and the destruction of the ponds. The event received local and national newspaper coverage, and the mayor was commended by the minister of the environment. With this widespread publicity, anyone else considering illegal aquaculture ponds must recognize increased risk to their activities, which translates into a lower expected rate of return on investment, and presumably less investment. Without effective communication, this project would have been relatively insignificant. With effective communication, it may end up influencing, however slightly, the rate of mangrove conversion in the Philippines. We have also learned that the web-based teaching module has been used in university courses in the Philippines. Though currently in need of updating and maintenance, we hope it will prove a useful resource for other groups working on similar issues, who are free to adapt, revise and expand it as they see fit.

Ominously, the Federal government reversed the decision to dismantle the aquaculture ponds and awarded a temporary permit to the shrimp pond operators to resume aquaculture operations three months after the workshop. However, the original decision was reinstated upon joint appeal by the city, local leaders and the Environmental Legal Assistance Center citing national laws prohibiting mangrove deforestation. Mayor Hagedorn has steadfastly refused to give permits allowing shrimp farming operations or other activities that would disturb or destroy the mangrove forests in the area. As of March 2009, no other shrimp aquaculture operations had been given lease agreements in Puerto Princesa.

Summary, Conclusions and Suggestions for Future Research

Given the results of our project, what can we say about its successes and failures, the lessons learned, and the implications for other researchers and conservation advocates? Summarizing our broader goals and specific project objectives, we sought to develop an effective approach to conservation, and to train a new generation of environmental problem solvers. To address the second goal (training), we involved students in a real life issue with all its ambiguity and uncertainty. Though we did not in this paper attempt to evaluate its success, we believe that it was indeed an effective approach. Many of the lessons learned can be found in Farley and others (2005).

To address the first goal (an effective approach to conservation), we sought to develop a transdisciplinary, transinstitutional approach to conservation that bridged the gaps between objective science and subjective values and between theory and action. Post normal science provided appropriate methods for achieving this. Effective communication proved critical to our results. We believe that any successful integration of research and advocacy requires a similar approach.

We recognize that many scientists will consider our approach unscientific, first because it fails to follow the conventional scientific method, and second because it involves advocacy. In response, we believe that integrating natural and social sciences is essential to solving complex problems (Berkes and Folke 1998). However, if the social sciences are to regain their relevance, they must stop striving to emulate the conventional scientific method, must address issues that really matter to the local, national and global communities, and must effectively communicate their results to their fellow citizens (Flyvbjerg 2001). Our work contributes to ongoing efforts to raise awareness of the ecological and socio-economic importance of mangrove forests and other ecosystems, to balance these benefits against the benefits from conversion, and to change the mainstream development narrative that favors private property rights over common property rights (Armitage 2002).

While we stand by the strengths of our approach, we must also reflect on at least four weaknesses so that others may avoid them. First, the atelier process is poorly suited to developing the types of strong community relationships and institutional ties that may prove essential to effective conservation in the long run. It must instead rely on close relationships with project partners, and trust that those partners have adequate relations with the local community.

Second, in complex adaptive systems, adaptive management is essential: actions should be treated as empirical tests of the underlying assumptions that drive them. Our project however concluded with recommendations for action, without subsequent observation and evaluation to see if recommendations were indeed achieving the desired outcomes, followed by critical reflection, and a new round of planning and action if they were not. While the atelier format itself does not readily allow for adaptive management, we could have worked with ELAC and other partners to build in such a strategy. Our reviewers mentioned as a shortcoming of this article failure to cite other relevant research. Reviewing the literature on collaborative adaptive management (e.g., Colfer 2005—unpublished at the time of our workshop) and participatory action research (Whyte 1991), for example, might have made us rethink our lack of mechanisms for adaptive management. Knowledge cannot progress as rapidly when it fails to builds on what has come before.

Third, as one of the article reviewers also pointed out, our workshop brought together an influential group of stakeholders which raised the profile of the issues we were addressing. While we consider this a strength of the atelier approach, there is an accompanying risk that results will be short lived. It would undoubtedly be more effective for researchers to develop long-standing relationships with local government and stakeholders, which elsewhere in the Philippines has turned into enduring protection of mangrove ecosystems (Walters 2003).

Finally, our efforts focused primarily on local and regional benefits, but mangroves and other ecosystems provide national and global benefits as well. While we influenced local decision makers, their decisions were almost overturned at the national level, in spite of national laws preventing continued mangrove conversion. The atelier might have been more effective had we been able to convince national level policy makers to attend, but institutional problems such as corruption, weak law enforcement and a lack of political will are serious problems and difficult to overcome (Primavera 2000). However, even the best-intentioned national level policy makers are unlikely to promote the management of mangrove forests for global benefits. Until those global beneficiaries of mangrove ecosystems who can afford to do so pay for the benefits they receive, optimal levels of conservation are unlikely. In the meantime, the wealthy nations are free-riding on the provision of ecosystem services by the poorer nations (Farley and others 2007a). It is a basic principle of ecological economics that solving problems demands institutions at the scale of the problem (Costanza and others 1998; Daly and Farley 2004). Conservation efforts must transcend international boundaries as well as disciplinary and institutional ones. How to achieve this is a critical area for future research.

We continually work to improve the approach described here. Interested readers can find descriptions of numerous ateliers around the world at http://www.uvm.edu/giee/ateliers and an open access, on-line course in ecological economics at http://metacourses.org/ecologicaleconomics/. They can also learn from the IUCN Mangroves for the Future Program, which is working to restore and conserve mangroves in the Indian Ocean by promoting them as critical coastal infrastructure for sustainable development. The approach integrates community action and private sector engagement with national program support and regional cooperation. It seeks to build knowledge, enhance governance and strengthen empowerment (IUCN 2006), and addresses several of the weaknesses in our approach. In conclusion, we hope that other conservation researchers and advocates can build upon the best elements of our approach while avoiding our shortcomings.

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