Managing Complexity: Ecological Knowledge and Success in Puerto Rican Small-Scale Fisheries

Carlos G. García-Quijano

SEDAR80-RD-15

May 2022

Human Organization, Vol. 68, No. 1, 2009

0018-7259/09/010001-17$2.20/1

Managing Complexity: Ecological Knowledge and Success in Puerto Rican Small-Scale Fisheries

Carlos G. García-Quijano

This paper examines the interrelationship between Local Ecological Knowledge (LEK) and success in the small-scale fisheries of Southeastern Puerto Rico (SE PR). Using mixed qualitative-quantitative ethnographic methods over 18 months of fieldwork, I investigated what constitutes success for small-scale fishers and what role LEK plays in helping them achieve success. SE PR fishers' models of success are geared towards socially beneficial goals such as resource sustainability and social household reproduction rather than towards profit maximization. For SE PR fishers, to be successful is to manage social and ecological complexity enough so they can make a living from fishing. Their LEK enables them to do precisely that and find predictable catches of fish in a heterogeneous, rapidly changing coastal and marine environment; at the same time, drawing on their LEK, they question and evaluate the actions of competing stakeholders for access to coastal and marine resources. Shared cultural models of success, as well as systems of LEK, are shaped by strategies to manage complexity and maximize predictability in sociocultural, economic, and ecological contexts.

Key words: local ecological knowledge, Caribbean, small-scale fisheries, cultural models, success, complexity

Introduction

Small-scale fisheries constitute a major source of food and economic activity for millions of people around the world even today in the post-Green Revolution World (Pauly 2006; Zeller, Booth, and Pauly 2007). Despite the massive growth of industrial fishing operations that have depleted many fishing stocks during the last century, most fish and shellfish used for direct human consumption come from small-scale fisheries (McGoodwin 1990; Pauly 2006; Pauly and McLean 2003). This is especially true for developing nations and regions located near the Tropics. One of the defining characteristics of tropical small-scale fisheries is that the activities of the fishers are guided by culturally-shared local or traditional ecological knowledge—as opposed to the Technical Knowledge or Western Scientific Ecological Knowledge (WSEK)[1] used by industrial fleets (McGoodwin 1990; Ruddle 1994). Thus, millions of people around the world are fed, nourished, and kept employed by small-scale fishers' LEK.

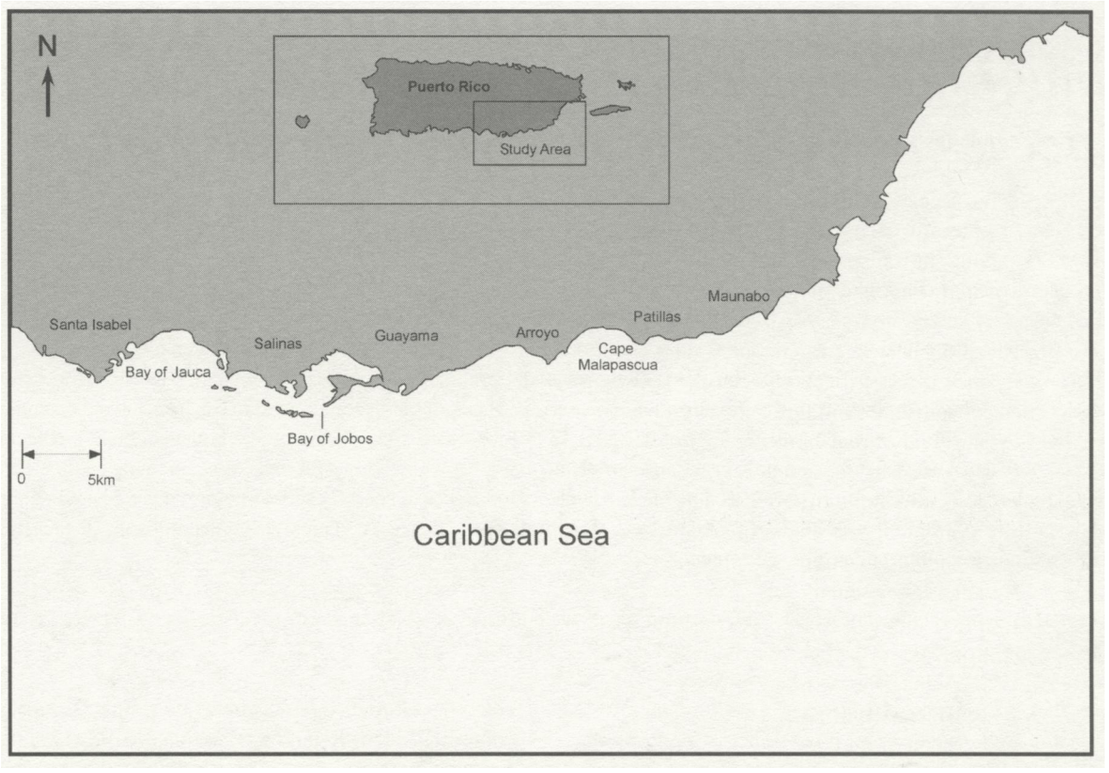
The theory and understanding of cultural knowledge are incomplete if we do not examine knowledge *in action*; it is, thus, important to combine analyses of shared cultural knowledge with research on the actual application of LEK in its local context (Menzies 2006). This article is based on two questions: (1) what do small-scale fishers want to achieve from their enterprise? and (2) how does their knowledge of local ecosystems help them achieve it? These two questions are important for several reasons.

First, any resource management scheme that intends to take into account the behavior of human resource users will need to know what these goals are (e.g., what constitutes "success" for resource users). Calling for a more thorough understanding of the "incentive structure of societies," institutional economist Douglass North (1993:1) asked, "How can one prescribe policies when one does not understand how economies develop?" Ethnography is a powerful way to explore these issues in detail and in meaningful context.

Second, documenting LEK is useful and valuable for resource management. LEK has been the focus of a growing body of literature that points to the importance of studying ecological knowledge held by small-scale natural resource users (e.g., fishers, farmers, hunters-gatherers) and further including this knowledge in resource management programs (Aswani and Hamilton 2004; Berkes 1999; Brush 1993; Gadgil

Carlos García-Quijano is an Assistant Professor of Anthropology at the University of Rhode Island and a Research Associate at the Institute for Interdisciplinary Research, University of Puerto Rico-Cayey. *First and foremost, he would like to acknowledge the collaboration and generosity of Puerto Rican fishers and their families, whom he cannot name to keep confidentiality. Their knowledge and insights are the basis for this research. The help, advice, and support of M. Valdés-Pizzini, B. Blount, D. Griffith, H.Lloréns, C.González, T.Rivera, I.Tirado, J.Casillas, B.Berlin, I. Godreau, T.Carlo-Joglar, M.Flores Mangual, and Monte were crucial for the realization of this research. Funding for this research was provided by an NSF Grant (BCS-0214211), a NOAA–NERR Graduate Research Fellowship (NAO3NOS4200058), and the NOAA–University of Puerto Rico Coral Reef Ecosystem Studies (CRES) Project. The Institute for Interdisciplinary Research at the UPR-Cayey provided valuable support during the writing of this article. David Griffith and two anonymous reviewers provided valuable feedback and suggestions which greatly enhanced this paper.*

Figure 1. Study Region in the Southeastern Coast of Puerto Rico



et al. 2003; Hunn et al. 2003; Johannes 2001; Menzies 2006; Paolisso 2002; Ruddle 1994). The continued experience of fishers with coastal environments, coupled with their LEK and the diachronic depth that their knowledge reaches through intergenerational communication, make them an important, but largely untapped, source of information about continuity and change in coastal ecosystems (Berkes, Colding, and Folke 2000; García-Quijano 2007; Johannes, Freeman, and Hamilton 2000).

The third reason is the adaptive value of LEK. LEK can be useful for the human groups who hold it in a variety of ways. It can serve to maintain group cohesion and identity in times of uncertainty (Posey et al. 1984), to illuminate the ever-challenging issues of allocating local resources (DeWalt 1994; Gadgil and Berkes 1991), and as a tool for traditional groups attempting to maintain control over their traditional territories and resources (Peluso 1995; Ruddle 1994). The main value of LEK, however, for small-scale fishers around the world, is that it helps them navigate their social and ecological systems and make a living from fishing.

Ethnographic and Ecological Context

Study Region and Environmental Setting

This research was conducted in the Southeastern Coastal Region of Puerto Rico (SE PR), comprising the coastal municipalities of Santa Isabel, Salinas, Guayama, Arroyo, Patillas, and Maunabo (see Figure 1). SE PR is a rugged coast of mountains that widens from East to West to give way to coastal agricultural plains and mangrove forests. Partly due to its physical geography, SE PR has been less developed and urbanized than other coastal regions of Puerto Rico, but due to growing population trends in coastal areas, this is likely to change.

One of the overarching themes discussed in this article is that the complexity of the SE PR coast shapes the local ecological knowledge needed for fishing. Tropical coastal ecosystems tend to have more habitat heterogeneity and higher numbers of species than their higher latitude counterparts (Sale 2002). Tropical marine ecosystems remain poorly understood by Western Science, in part because of their heterogeneity but also because most lie under the jurisdiction of relatively poor "third world" countries, far from the temperate ecosystems where most Western scientists live (Johannes 1998; Pauly 1994).

For more than 40 million years, Puerto Rico has been at the leading edge of the moving Caribbean Tectonic Plate as it grinds against the North American Plate (Krushensky and Schellekens 2001). A dynamic geological history has resulted in a coastline in which patchiness and discontinuity, rather than uniformity, dominate the landscape (Morelock, Ramírez, and Barreto 2002:2). Over a few square kilometers of coastal

area, fishers can find a variety of coral reef formations (patch reefs, fringing reefs, spur-and-groove reefs, and submerged deep-water reefs), seagrass prairies and sand bottom areas, mangrove forests and mangrove channels, a large estuary, and mud flats. Each habitat type is characterized by different combinations of ecological parameters such as water turbidity, salinity, depth, bathymetric relief, availability of nutrients, and floral-faunal assemblages (Jackson 1991; Sale 2002).

The bathymetry and composition of these coastal habitats is ever-changing. Reef corals tend to build upwards by creating massive calcium carbonate structures that may modify currents, sediment transport, and availability of nutrients through the area (Fagerstrom 1987). Red mangrove (*Rhizopora mangle*) stands and seagrass pairies can act as sediment traps and rapidly change coastal morphology (Kathiresan 2003; Woodroffe 1992). Likewise, estuarine sediment deposition can affect nutrient availability, water turbidity, and even affect the survival of reef-building corals offshore (Cortés and Hatziolos 1999). To these natural processes that result in natural ecological complexity we can add the effect of human activities along the coast, including deforestation, recreational activities, industrial activities, and fishing, which can also cause rapid ecosystem change.

The factors outlined above illustrate the enormous challenge of managing tropical reef-estuarine fisheries like those in SE PR. It is hard to predict ecosystem responses to management, and what is considered state-of-the art knowledge of the ecosystems changes very rapidly (Munro 1984; Polunin, Roberts, and Pauly 1996; Pomeroy 1992). Even in reefs and associated systems that are located close to large populations in the Caribbean, new species of fish are still being discovered. In January 2006, an international team of marine scientists reported close to 200 new species of fish discovered in the Caribbean island atoll of Saba, located less than 300 miles from Puerto Rico (Conservation International 2006). Many of these species had been known to local fishers for years.

Fishing

Puerto Rican fisheries are small-scale, being predominantly operator-owned with low capital investment, household level management, and oriented towards petty commodity, informally marketed production (Griffith and Valdés-Pizzini 2002; Pérez 2005; Valdés-Pizzini 1987). Small-scale fishing often relies on sophisticated bodies of local knowledge (García-Quijano 2007; Griffith 1999; Johannes 1981; Ruddle 1994), which is often transmitted and updated across generations (Figure 2). Despite periodic episodes of moderate to heavy investment by the Puerto Rican government to promote fisheries modernization, practically all fishing activity continues to happen at the small-scale (Pérez 2005).

Resource Species

More than 150 coastal, reef, and estuarine species of fish, crustaceans, and mollusks are routinely fished in Puerto Rico (Griffith, Valdés-Pizzini, and García-Quijano 2007; Suarez-Caabro 1979). As with other tropical fisheries in the Caribbean, most of the economically important fish species belong to the snapper (Lutjanidae), grouper (Serranidae), grunt (Haemulidae), mackerels and tunas (Scombridae), jack (Carangidae), and parrotfishes (Scaridae) families. Mollusks such as the Queen Conch (*Strombus gigas*) and the common octopus (*Octopus vulgaris*) are also economically important, as well as crustaceans like the spiny lobster (*Panulirus argus*). Also important and routinely captured are bait species such as mullets (Mugilidae), anchovies (Engraulidae), sardines and herring (Clupeidae), and half-beaks (Hemiramphidae) (Suarez-Caabro 1979). Some species of fish are not of major commercial importance, but, according to ethnographic data, are very important food fish for local consumption. This is the case of fish such as the snook (*Centropomus undecimalis*), and the spotted goatfish (*Pseudupeneus maculatus).*

Figure 2. The Transmission of LEK. In the coastal village of Aguirre in Salinas, Puerto Rico, a fisher instructs a young apprentice in the intricacies of casting a handline for baitfish. The apprentice watches attentively. Photo by H. Lloréns (2005).

Fishing Vessels

Yolas are the most widely-used small-scale fishing vessels in Puerto Rico. A yola is a locally-made flat-bottom wood or wood-and-fiberglass boat that typically ranges in size from 10-25 feet long. Yolas are typically operated with a small outboard engine. The use of yolas spread after the 1970s, when state-sponsored programs to develop fisheries in the island engaged in promoting and subsidizing the use of small outboard engines (Pérez 2005; Valdés-Pizzini 1987). Nowadays, virtually all fishers around Puerto Rico routinely use outboard engines to go out to sea.

Fishing Gear

Similar to other multi-species tropical fisheries, a wide variety of fishing gears are used to capture fish in Puerto Rico (Griffith, Valdés-Pizzini, and García-Quijano 2007; Suarez-Caabro 1979). Fishing gear in Puerto Rico is generally locally made and inexpensive, and it probably is the single best material indicator of the small-scale nature of Puerto Rican fisheries. Fishery landings data for 1999-2003 for Puerto Rico lists 20 different fishing gear varieties, with five gear varieties accounting for over 90 percent of the landings (Griffith, Valdés-Pizzini, and García-Quijano 2007).

Fisheries and Uncertainty

As an economic activity, fishing in SE PR has long been about managing and offsetting complexity and unpredictability. Small-scale fishing has been an important part of peasant/rural coastal subsistence in SE PR for at least 300 years (Griffith and Valdés-Pizzini 2002). Over this span of time, coastal ecosystems have provided high-quality protein, and independent full-time or supplementary livelihoods to coastal communities that have otherwise depended on often unstable and unpredictable labor markets in large-scale agriculture and industry (Griffith, Valdés-Pizzini, and García-Quijano 2007). Sugarcane harvesting dominated the economy of SE PR from the mid-18th century until the late 20th century (Dietz 1986; Figueroa 2005). Fish and shellfish caught by local fishers were often the only protein available to sugarcane laborer communities during the "*invernazo*"—a dead season of sugarcane harvesting during which income was severely reduced and often suspended and which could last up to seven months a year. The fishers with whom I collaborated throughout this study also held jobs as varied as nurse, farmer, boat builder, master welder, policeman, mechanic, fireman, leather worker, truck driver, carpenter, and agronomist.

After the demise of the sugarcane industry in SE PR in the early 1990s, coastal industrial complexes—mostly pharmaceuticals and power generating plants owned by multinationals—have substituted sugarcane operations as main providers of employment in the area. These coastal industries have proven unreliable employers, as they are prone to massive layoffs due to downsizing, factory closing, and relocation of operations in search of tax breaks and cheap labor. They have also polluted local waters and damaged local habitats. However, fishing and associated activities still serve as a source of quality food and supplementary employment for at least some of those being affected by labor market fluctuations.

State regulatory agencies are also sources of uncertainty and challenges for fishers. Widespread conflicts between Puerto Rican fishery management agencies and small-scale fishers have arisen over the last decade (e.g., Pinto 2004; Vargas Saavedra 2004). A key issue in these conflicts has been the passing of new fishery regulation codes by Puerto Rico's Department of Natural and Environmental Resources (DRNA). Fishers think that these codes are too restrictive of their ability to make a living out of fishing, while not enough attention is being paid to other, more important sources of fish mortality such as coastal development-induced pollution and habitat degradation. Recent WSEK research on the causes of reef-estuarine ecosystem degradation in the Caribbean seems to support the fishers' versions that habitat degradation and coastal pollution are important, albeit often overlooked, sources of fishery species mortality (Mora 2007; Mumby et al. 2004; Nellemann, Hain, and Alder 2008).

Small-scale fishers operating within modernized economies such as Puerto Rico often engage in multiple livelihoods, occupying intermediate/ambiguous positions between a traditional subsistence depending on local ecosystems and a "modern," proletarian subsistence, engaged with larger labor markets (Griffith 2006; Griffith and Valdés-Pizzini 2002; McGoodwin 1990). Griffith and Valdés-Pizzini (2002) have shown that in Puerto Rico, fishing is part of a complex household economy of episodic *labor* (in the proletarian sense of agricultural and industrial laborers) and subsequent *refuge* (in fishing and interaction with coastal ecosystems). Fishers' ability to catch fish—and thus their LEK—provides them with a source of livelihood they can always fall back on while they navigate the harsh and unpredictable local labor markets (Griffith and Valdés-Pizzini 2002; Pérez 2005). Fishers also rely on their LEK to critically evaluate and, if necessary, resist the actions of competing stakeholders (García-Quijano 2006).

Methods

This research results from fieldwork conducted over 18 months, between February 2003 and September 2004. During those 18 months, I lived in coastal Barrio Machete, in Guayama, Puerto Rico. Most field activities consisted of interviewing fishers in the study region, but I also spent considerable time going out to fish as a participant observer and attending fishers' political meetings and rallies. Thereafter, I have made repeated visits during which I conducted follow-up interviews and presented my findings to fishers for their comments. These visits have taken place in December 2004, March 2005, June 2005, June 2006, and November 2007.

Research Design

This research had four specific objectives: (1) To systematically document ecological knowledge held by fishers in southeastern Puerto Rico, with an emphasis on the kinds of knowledge that are directly important for the fishing activity; (2) To document fishers' folk models of success, with an emphasis on what it means to "*be a successful fisher*" in the study region and what constitute the perceived determinants and indicators of success; (3) To measure intragroup variation in knowledge and in success among fishers based on results from the previous two objectives; and finally, (4) To

Table 1. LEK Assessment Questions Administered to Structured Questionnaire Respondents

Question (Translated and Paraphrased from Spanish Questionnaire Format)	Answer Format	List of Species Used for Question
Q. LEK1. I would like to ask you to tell me in which kinds of environments the following fish/shellfish are found. Please use your own words.	(species local name) is found in: _____	16 important/salient species
Q. LEK2. I would like to ask you to tell me at what times of the year are the following fish/shellfish found.	(species local name) is found: _____	16 important/salient species
Q. LEK3. I would like for you to tell me whether the following fish/shellfish species are usually found alone, in groups of the same species, or in groups with other species.	(species' local name) is found: 1) alone, 2) in same-species groups, 3) with other species, or 0) do not know	16 important/salient species
Q. LEK4. I would like to ask you what kind(s) of fishing gear are used to capture the following fish/shellfish. Are the following fish caught with (recite different kinds of gear)? Please indicate as many kinds of gear as are used for the species.	(species' local name) is captured with: 1) fishpots, 2) surface nets, 3) bottom nets, 4) bottom hook-and-line, 5) troll surface line, 6) diving, or 0) do not know	16 important/salient species
Q. LEK5. I would like to ask you about fish that are caught in deeper waters. At what depths are the following fish/shellfish species found?	(species' local name) is caught at: _____ depth in 'brazas' (depth unit similar to a fathom)	12 deep-water or bottom line-caught species

empirically test whether there was a significant correlation between LEK and success.

I worked on these four objectives successively over two complementary, qualitative and quantitative, research phases. The research design allowed me to (1) gain a firm understanding of the context, content, and richness of fishers' LEK and cultural models of success through participant observation, conversations, and open-ended interviewing with widely-recognized expert fishers, and (2) measure intracultural variation in ecological knowledge and ideas about success with a structured questionnaire that included general demographics, characteristics of fishing and household economic activities, locally-relevant measures of success in fishing, and ecological knowledge assessment questions based on results of key informant interviews. I used snowball sampling to identify 20 expert fishers in the study area in order to maximize my access to expert knowledge about fishing (Johnson 1990).[2] The expert fishers were invited to participate in four to five semi-structured interviews about their involvement with fishing, perceptions of problems with the fishery, the types of knowledge they use to make a living from fishing, and what it means to be a successful fisher. Eighty-six interviews were conducted with the 20 key informants. Most analysis of qualitative phase data consisted of text analysis with Atlas.ti qualitative analysis platform (Muhr 2004).

Based on key informant interviews, I outlined shared cultural models of success and local ecological knowledge, how success is manifested among fishers, and how LEK could be related to success (research objectives 1 and 2). Structured questionnaire interviews were conducted with a stratified random sample of 41 fishers (not including the key informants).[3] The structured questionnaire respondents were chosen from a combination of local fishing license records and lists of fishers generated locally (García-Quijano 2006). Agreement (or consensus) with the collective sample on a series of Ecological Knowledge Assessment Questions (Table 1) was used as a proxy for individual knowledge (Romney et al. 1986).

Variation in success was measured by peer ratings of success (i.e., asking fishers in the sample to rate other fishers's success in a 4-point Likert scale ranging from very successful to not successful at all). This technique is a modification of the "key informant rankings of success" technique used by Poggie (1979) with fishers in Southwestern Puerto Rico. Ratings were used instead of rankings to allow for a slightly larger universe of respondents where most participants, but not all of them, know each other.

Regarding the relationship between LEK and success in small-scale fishing, the principal hypothesis of the study was that, other things being equal, more knowledgeable fishers would tend to score higher in culturally-relevant measures of success. Strength of association between LEK and success was measured using correlation techniques. To overcome limitations related to sample size (n=41), I used ResamplingStats 5.0 (Simon 1997) to calculate exact distribution confidence intervals and p-values for the observed correlations. Statistical tests were run in JMP 7.0.1 (SAS 2007).

Results

Fishing Success—Goals and Motivation

For the majority of the key informants, success in fishing meant raising a family, providing fish to their community, and being able to keep fishing for a living. Teófilo[4] (personal communication, September 2003) a widely respected fisher from the coastal village of Aguirre in Salinas, Puerto Rico answered the question of what fishers want to achieve by engaging in fishing:

> You have to live from fishing two or three years to come to understand what I am going to tell you—to know "*cómo es que se bate el cobre*" (how things work in the real world), how things work, how does one make a living from fishing, and how hard it is to maintain a family from fishing.

> Why do we fish? Because being a fisher, you being a fisher and being able to bring nourishment to your community, and you enjoying the work you do…ah! One feels fulfilled and satisfied. [It is] because one lives for the benefit of a community. And the community helps you in your daily life, because of the quality of the fish that you bring back from the sea. This is how it is. Do you understand me? Fishing is what we call honorable work.

Teófilo's statement above encapsulates what I found to be the three principal goals of a fisher: (1) to be able to make a living and sustain a family from fishing (household reproduction (Griffith 1985; Pearse 1975), (2) to maintain positive reciprocal relationships with their communities by bringing back fish from the sea, and (3) to be able to maintain a lifestyle that at least partly depends on fishing. Most key informants (18) mentioned these three goals when describing what they wanted to achieve by engaging in fishing. The central place of these goals in fishers' discourse could indicate that they represent high-level cultural models, important in motivating behavior (D'Andrade 1992).

Every fisher that I talked to during this research told me that they valued fishing because they were or had been able to raise their families and care for the members of their families through fishing. Pablo (personal communication, October 2003) a fisher from Guayama, underscored the importance of fishing for his household economy by detailing how he was raised from fishing, and in turn he raised his children by fishing:

> I am now 64, and of 16 siblings 12 are still alive. My old man raised us from fishing. I survived from his fishing. At 10-12 years old, I started to go fishing with him. Fishing is what I love…. Me and my wife, my five children, they are all raised from fishing. I supported this family from fishing. They went to school! I tell my daughters, 'Now you have a television in your room. You went to the university and everything.' And it all has come from fishing.

Pablo also hinted, by pointing out that a high proportion of his siblings have made it to old age, that his parents' involvement in fishing helped spare their household from the high infant mortality often faced by mid-20th century rural poor Puerto Ricans.

Eddie (personal communication, November 2003) an elder fisher from Santa Isabel, illustrated his beliefs about success by describing another fisher whom he thought was very successful:

> There is a fisher from around here, a friend of mine, his name is Enrique, that I think he is a very successful fisher. He is a long-liner, and he has dedicated his life to fishing. I admire him because he goes out to sea at dusk and comes back early the next morning. And this is how he has raised and sustained his family.

First and foremost, the key informants wanted to make a living for themselves and their families from fishing. The emphasis seems to be on *maintenance*, *subsistence*, and *reproduction* rather than on *profit* or *returns*. Not one of them mentioned maximizing catch, CPUE, or economic gain as a goal. The intention to maximize profits, a motivation for behavior that is often assumed in economic modeling and predictions, was not part of SE PR fishers' widely shared cultural model of success. As Paul Durrenberger (1997:158) put it in his work with Mississippi shrimpers, fishers "are not firms."

Success Is Achieving Predictability Among Complexity

Puerto Rican small-scale fishers make a living in a social and ecological system that is characterized by heterogeneity and rapid change. The need to adapt to these characteristics is a shaping force for fishers' livelihoods. Risk and uncertainty management have resulted in a pattern of mixed subsistence strategies and continued small-scale fishing. These results resonate with work on peasant economies which proposes that working class people who depend on natural resources and thus face risks inherent to ecosystem dynamics (fishers face the additional risks of capsizing, loss of equipment, and drowning on a daily basis) tend to take a safety-first, risk minimizing approach to economic behavior (Chayanov 1966; Scott 1976:24).

The concern with community reciprocity also seems related to risk avoidance and managing uncertainty. One of the ways fishers and other small-scale resource users manage uncertainty is by cultivating social capital through reciprocity networks (Dick 1996; Griffith 1999; Pollnac 1998). By bringing back fish from the ocean, fishers become the starting point of networks that revolve around the marketing and sharing of fish and fish products. As Teófilo put it, "…the community helps you in your daily life because of the quality of fish that you bring back from the sea."

Just being able to spend time in the sea, in contact with their local ecosystems, is a rewarding experience that merits spending considerable effort and sacrifice to keep. Many fishers report having gone to great lengths and great sacrifices to keep on fishing, or at least maintain the possibility of fishing. Enjoyment and love of fishing is certainly a reason for this, as is the fact that many small-scale fishers see their

Table 2. Lists of Species Used in LEK Assessment Questions

16 Important Fishery Species			12 Bottom-line Captured Species		
Spanish	**English**	**Scientific**	**Spanish**	**English**	**Scientific**
sama	mutton snapper	Lutjanus analis	colirrubia	yellowtail snapper	Ocyurus chrysurus
sierra carite	Spanish mackerel	Scomberomorus maculatus	sama	mutton snapper	Lutjanus analis
sierra canalera	king mackerel	Scomberomorus regalis	arraya'o	lane snapper	Lutjanus synagris
colirrubia	yellowtail snapper	Ocyurus chrysurus	moniama	cardinal snapper	Pristipomoides macrophtalmus
arraya'o	lane snapper	Lutjanus synagris	negra	blackfin snapper	Lutjanus bucanella
mero cabrilla	red hind	Epinephelus guttatus	chillo	silk snapper	Lutjanus vivanus
mero común	red grouper	Epinephelus morio	cartucho	queen snapper	Etelis oculatus
carrucho	queen conch	Strombus giga	mero guasa	misty grouper	Epinephelus mystacinus
jarea	white mullet	Mugil curema	mero guajil	yellowfin grouper	Mycteroperca venenosa
boquicolora'o	striped grunt	Haemulon plumierii	mero cabrilla	red hind	Epinephelus guttatus
langosta	spiny lobster	Panulirus argus	mero batata	Goliath grouper	Epinephelus itajara
pejepuerco	queen triggerfish	Balistes vetula	mero cherna	Nassau grouper	Epinephelus striatus
chillo	silk snapper	Lutjanus vivanus			
salmonete	spotted goatfish	Pseudupeneus maculatus			
pulpo	octopus	Octopus vulgaris			
loro	parrotfish	Sparidae			

cultural and personal identity as being closely tied to fishing. Keeping close ties to the fishing lifestyle also affords fishers the opportunity to earn income that is relatively free from the constraints of proletarian labor relations and the fluctuations of labor markets, by providing an alternative means of making money for their household and providing a fallback should they lose a job or quit an undesirable position (Griffith, Valdés-Pizzini, and Johnson 1992; Griffith and Valdés Pizzini 2002; Pérez 2005). Even fishers who migrate to work in the mainland United States keep the possibility of fishing alive, monitoring changes in fisheries back home by communicating with fishers who stayed behind and keeping their memories of and attachment to home ecosystems alive by imagining and reviewing coastal landscapes in their minds. Edgar (personal communication, October 2003), a fisher from Salinas, describes this process within a story of homesickness for the familiar ecosystem and the fishing lifestyle:

> I went to the United States, to New York, once. I worked as a stevedore and I made good money. Oh, I still remember those [times]! I walked around lost, in the streets, tears in my face. I told myself, 'I cannot stay here, this cannot go on.' All I thought about was the mangrove channels, the keys, the fish. During the day, I surveyed them in my mind; at night, I dreamed about them.
>
> And, one day, my friend who had found me the job [in New York] told me, 'Look, Edgar, I feel bad because you work very well, you are a nice young man, and you are very good to us. But, if you go on like this you are going to die! When you got here you were a robust man, and now look at yourself!' I had lost 40 pounds. I was gaunt, dry! I had to buy [smaller] clothes and all that. They took me to the doctor and the doctor said, 'But this man is healthy! He just does not eat!' And it was true. I [still] do not know what the devil was happening to me. But as soon as I returned [to Puerto Rico] and went fishing, I got my appetite again. I got here and right away (makes a sound like that of a balloon getting filled with air) I got fat again. If I had stayed there for six more months, I would have returned inside of a pine box!

Determinants and Indicators of Success

Table 3 shows indicators of success mentioned by key informants and how I operationalized them in the structured questionnaire to develop and evaluate measures of variation in success that were both reliable and culturally relevant.[5] Echoing previous findings by Poggie (1979) who found that reputation among peers was a reliable proxy for success for small-scale fishers in Puerto Rico, I reconfirmed that *reputation as a successful fisher* was the best indicator for measuring variation in success. Material measures, such as boat size, home ownership, value of fishing gear, and material standard of living, were mentioned by some fishers and were measured in the structured questionnaire. These were, however, confounded by occupational multiplicity and variable degrees of involvement in fishing over space and

Table 3. Indicators of Fishing Success Mentioned by Expert Fishers

Indicator of Success	Operationalized as:
Material standard of living	Material culture index
Percent income derived from fishing	Self-reports in structured questionnaire
Home ownership	Self-reports in structured questionnaire
Reputation as successful fisher	Peer ratings of success

time, as well as by variation in individual attitudes towards material possessions (see Guest 2000).

Each of the 41 fishers who responded to the structured questionnaire were rated in their success by at least 10 other fishers in a 4-point Likert scale, with (4) Very Successful and (1) Having Little Success. The average rating for these 41 respondents was 2.96 (Std. Dev.=.69).

Why Not Use Individual Landings as a Measure of Success?

At the beginning stages of this research, I had hoped to obtain records of individual fishers' landings and use them as a measure of success. Based on ethnographic work, I found that individual fishery landings from state agencies' records, if they were obtainable, were unreliable. Fishers throughout this study repeatedly told me that a common method of resistance against regulations was to purposely report inaccurate landings to the Puerto Rico Fishery Statistics program or not to report any landings whatsoever. The misreporting of yields, profits, and activities is a commonly used method of resistance used by small-scale resource users to resist unilateral regulation from outside agencies (e.g., Scott 1985, 1998). This is further confounded by the episodic and patchy distribution of fishers' participation in fishing due to occupational multiplicity.

Most importantly, fishers themselves do not measure success in CPUEs. Because the ultimate goal of many small-scale fishers in this area is to ensure reproduction and economic survival of the fishers' extended household, the predictability and sustainability of access to moderate amounts of fish is more important that the magnitude of landings themselves. Catching too much might in fact be deleterious to success, as a fisher who fishes too much or too carelessly may negatively impact the resource and, thus, face disapproval and sanctions from fellow fishers.

Local Ecological Knowledge

Fishing means life, because as long as there is a variety of [fish and shellfish] species near our coasts, we fishers will be able to survive.

Lázaro, a fisher from Patillas, Puerto Rico.

Lázaro uttered the words quoted above during our first interview in Patillas, Puerto Rico. Two very important characteristics of the ecology and ethnoecology of fishers in this study's region are represented in Lázaro's words. First, fishers equate their survival with the health of the ecosystems they depend on. Second, due to the ecological structure of tropical estuarine and reef fisheries (high total biomass which is distributed among many species that have relatively low biomass), fishers recognize that they rely on continued biodiversity of the ecosystems as well as on total productivity of ecosystems. Key informants (specially the eldest among them) talked extensively about the times when coastal ecosystems appeared healthier than today. Of the 21 informants, 18 used the phrase "*variedad the peces*" (variety of fish) instead of "*muchos peces*" (a lot of fish) when describing a healthy coastal ecosystem.

LEK Enables Fishers to Manage Complexity and Uncertainty

How do fishers make sense of the large amount of ecological and biological information needed to succeed in fishing? One of the phrases most frequently repeated by the key informant fishers throughout the interviews about important ecological knowledge was "*conocer las áreas de pesca*" (to know the fishing areas).

The fishing areas are places where fish can be caught. The fishing areas for different fish and shellfish will vary in factors such as bottom/substrate composition, depth, salinity, water turbidity, sediment input, currents, nutrients, prey species populations, and the species assemblages found. These ecological parameters (Johnson, Mason, and Raven 1968) determine what species can be found by fishers and in what quantity. Because these parameters can change over time in a particular underwater locality, fishing areas can and do change over time. Some localities, such as specific seamounts, reefs, and seagrass prairies have been productive fishing grounds over time, and, thus, they become a widely known, named fishing area. A named fishing area such as "Berbería," "Investigador," "Los Guajiles," and "Media Luna" (all important SE PR fishing areas), however, almost invariably refers to a relatively large geographic location. Inside of these locations, fishers have to find smaller fishing areas, such as "veriles," transition zones between reefs and seagrasses, which with

they actually interact (see also Forman 1967).

In our third interview, Teófilo (personal communication, November 2003) gave me a useful explanation of this usage of the term "fishing area:"

> You know, not all of the areas along these coasts are adequate for fishing, let's say to put a fish pot in the water. For you to use a fish pot, you have to be near the 'veriles' [boundaries between different bottom types], near the rocky bottom where fish abound. Because if you put your fish pot, let's say in a sand flat, where the fish you want are not abundant, far from the reefs or the 'veriles' or seagrasses, the movement of the fish will not work in your favor.
>
> The sea is immense, but it has areas, fishing areas, where you can fish. And you have to know these fishing areas. If you fish where the fish are not abundant, you are not going to have a good catch. You have to ask yourself, 'Where are the fish?' [It is] where food is abundant. [It is] where there are reefs, or seagrasses, or mangroves, places where there is protection for fish and food that the fish can eat. This is the most important knowledge—to know the kinds of places that are good fishing areas.

In the statement above, the ecological parameters that define a fishing area are: (1) the type of habitat, defined by the type of bottom substrate, and (2) availability of food for the pursued species. A fishing area may only be considered as such during certain times of the year. Thus, seasonality also has an effect on what is considered a fishing area (Cordell 1974). Although seasonality in tropical ecosystems is less dramatic than in temperate systems, the key informants reported that many species are predictably seasonal in their movements between habitats and/or geographic locations. Recent research in tropical Pacific fisheries has found that fishers move their fishing effort between habitat patches as productivity varies through the seasons (Aswani and Lauer 2006). Pablo (personal communication, December 2003), a trap fisher from Guayama, discussed seasonality of fish movements and of fishers' activities during one of our interviews:

> CGG: So you say this (December) is the time of lobster fishing? So there are other times of the year that you practice different kinds of fishing?
>
> Pablo: Yes. The lobster (*Panulirus argus*) likes the cooler water, so it comes nearshore on the colder months. The red hind (*Epinephelus guttatus*) season is coming next, in January and lasts until March. After that, in the summer, one can catch a variety of fish. Lobster becomes scarce, but there are more fish. You can catch a few hundred pounds of fish and 20 pounds of whatever lobster is left each week. You can catch trunkfish (*Lactophrys trigonus*), stone crab (*Carpilius corallinus)*, fish that one can always sell well.
>
> CGG: Is that in the summer?
>
> Pablo: Yes, in the hotter months. Most fish go away with the cold waters in this time of the year, but then lobster comes near the coast and that makes up for it.
>
> CGG: And what else do you fish throughout the year?
>
> Pablo: In the summer, we go to the offshore banks. In the lobster season, we fish mostly in *rastreales* (local habitat classification meaning rocks interspersed with sand). The lobster likes that area better than the large coral heads in the reefs. Then, when the lobster goes away to deeper waters, we move to the banks again. We catch red hind and queen triggerfish (*Balistes vetula*) in the reefs near the banks.

To fish effectively among the ecological complexity and biomass distribution characteristic of southeastern Puerto Rico, the most important ecological knowledge is to be able to place desired resource species in the context of a larger ecosystem. Encyclopedic knowledge of fish species (for example, the high value spiny lobster), which is needed to pursue a particular species, is invoked by the fisher in the context of a fishing area. Rather than interacting only with the fish they capture and sell, fishers interact with an underwater/seascape much in the way people on land interact with terrestrial landscapes. Gerónimo (personal communication, January 2004), an elderly fisher from Aguirre, explained to me how, when thinking about finding Spanish mackerel (*Scomberomorus maculatus*), fishers have to think about other components of the ecosystem that are associated with the fishery species (in this case, the mackerel's prey):

> When we are thinking about finding some mackerel, we cannot think only about the mackerel because these fish are *de carrera* (pelagic, migratory fishes) and they move, looking for food. If they come to these bays or these reefs, they come after the food—the baitfish, the sardines, the scad, the ballyhoo. If the food goes, they go. First, we find where the food is. Then, we use our nets or our troll lines. But first, we have to know that where the food is, the mackerels will be.

LEK Assessment Questions

Based on free lists of important fishery species, I built a list of 16 species that in the opinion of the key informants were important for local fisheries. To verify that these 16 species were considered as important by the structured questionnaire respondents, I asked the respondents to rate these species on a 4-point scale according to their importance. The average answer for all of the 16 species was "very important." Using a list of these 16 species, I asked the fishers: (1) In what kinds of habitats are the species most commonly caught; (2) In what times of the year are the species most commonly caught; (3) With what types of fishing gears are the species captured; and (4) Whether the species are usually found alone (solitary), in mono-specific groups, or together with other species. Similarly, I used a list of fishery species that are caught using bottom lines, including deep-water snappers, to ask about at which depths the fish are commonly found. Tables 1 and 2 show the ecological knowledge assessment questions used in the structured questionnaire and the lists of species used to ask the questions.

Table 4. Consensus Analysis First and Second Eigenvalues for Structured Questionnaire Respondents' Answers to Ecological Knowledge Assessment Questions

Ecological Knowledge Assessment Question	Variable	1st Eigenvalue	2nd Eigenvalue	1st:2nd Eigenvalue ratio
Where species are found	WHERE**	15.880	1.986	7.994
Season when species are found	SEASON**	13.022	2.426	5.367
Species' aggregation habits	AGGREG**	13.320	4.253	3.132
Gear used to capture species	CAPGEAR**	11.348	2.896	3.919
Depth at which species are found	DEPTHFIND*	10.433	2.995	3.483
Mean				4.779
Standard Deviation				1.988

* - Used modified species list
**- Used 16 salient species

Intracultural Variation in Ecological Knowledge

I measured patterns of agreement and disagreement in ecological knowledge by comparing questionnaire respondents' answers to the Cultural Consensus Model (Romney, Weller, and Batchelder 1986). The calculations were done with Consensus Analysis in ANTHROPAC X (Borgatti 2001). There is debate in the literature as to whether consensus reflects true knowledge of a domain of knowledge in which correct answers are not known (Brewer 1995; Furlow 2003; Romney 1997; Ross 2004). Under some assumptions, agreement can be considered to be a measure of true knowledge or competency in a subject. These assumptions are: (1) The questions ask about topics that deal with the same or very similar domains of knowledge; (2) There is a logical independent process or constraint that will tend to result in more agreement between more knowledgeable individuals compared with less knowledgeable individuals (i.e., there are correct answers, even if the researcher does not know them); (3) The informants being compared can be reasonably assumed to share a cultural model regarding the questions asked; and (4) A single shared cultural model is driving responses to the questions (Romney, Batchelder, and Weller 1987; Romney, Weller, and Batchelder 1986; Romney 1997).

The data about ecological knowledge gathered in this study seems to meet these assumptions. (1) The seven ecological knowledge assessment questions measure fishers' ecological knowledge. (2) There are correct answers to the questions asked, and a fishers' success in finding fish over time will reinforce answers that more closely reflect what goes on underwater in marine environments. (3) All of the structured questionnaire respondents fish for a living, thus, they can reasonably be expected to share a cultural model of expertise in fishing, even if they vary in their knowledge. (4) Large (Average 4.779, Std. Dev. 1.988) first-to-second eigenvalue ratios were found for the answers to each of the seven ecological knowledge assessment questions, which suggests a good fit of the observed responses with the cultural consensus model (Table 4). There is high probability that, for each question, a single cultural model was driving the observed responses (Handwerker 2002; Kempton, Boster, and Hartley 1995).

Estimated knowledge, or cultural competency, is the degree to which each respondent's answers coincide with the estimated "culturally correct" answers for each question (Borgatti 1996). Hereafter, I will refer to the structured questionnaire respondents' estimated knowledge scores as *ecological knowledge scores*. Table 6 shows the range of variation of scores for each of the ecological knowledge assessment questions, while table 6 shows correlation of informants' scores across questions. The task involving matching habitats

Table 5. Descriptive Statistics of 41 Respondents' Scores on Five Ecological Knowledge Assessment Questions

Variable name	mean score (n=41)	Std. Dev.	min.	max.
WHERE**	0.6022	0.1611	0	0.85
SEASON**	0.5366	0.1733	0	0.8
AGGREG**	0.5422	0.1793	0	0.84
CAPGEAR**	0.5056	0.1458	0.04	0.69
DEPTHFIND*	0.4583	0.2107	0	0.74

* - Used modified species list
**- Used 16 salient species list

Table 6. Pearson Correlations Between Respondents' LEK Scores Exact P-values were Calculated with ResampleStats 5.0 (Simon 1997)

	WHERE	SEASON	AGGREG	CAPGEAR	DEPTHFIND
WHERE	1	.450(***)	.354(**)	.404(***)	.428(***)
SEASON	_	1	0.265 (*)	0.073	0.11
AGGREG	_	_	1	0.178	0.251
CAPGEAR	_	_	_	1	0.056
DEPTHFIND	_	_	_	_	1

(***) significant at 0.01 level (2-tailed) (*) significant at 0.1 level (2-tailed)
(**) significant at 0.05 level (2-tailed)

and species seemed to be driving variability in ecological knowledge scores (75% of variability, PCA with Varimax). This reinforces the finding from key informant interviews that matching species to habitat types is the most important ecological knowledge a fisher must have.

The culturally correct answers for the LEK questions represent the consensus of the interviewed fishers' knowledge about fishery species' ecology and can be a starting point for the sharing of knowledge between fishers and government/academia scientists. For example, looking at the answers for the mutton snapper (*Lutjanus analis*) we can see that, according to the respondents, this snapper is: (1) found/captured most often at or near reefs, (2) caught more often during the summer months, (3) usually found in aggregations of the same species, (4) most often caught with bottom lines, and (5) usually found at less than 20 fathoms depth.[6] This is very specific information gathered in collaboration with fishers, which can be compared to the available western/scientific information and further used to complement, supplement, or validate information available to resource managers.

Ecological Knowledge and Success

Survey respondents' average peer-assessment success ratings were significantly correlated with their LEK agreement scores in questions about species-habitat matching, species aggregation patterns, depth at which species are found, and the season when species are captured (see Table 7). Success ratings did not correlate significantly with scores on fishery species-capture gear matching. An aggregated ecological knowledge variable was created by assigning each respondent a score for the first underlying factor identified by a Principal Component Analysis of LEK scores. Success ratings correlated significantly with respondents' scores on this variable.

The strongest correlations of LEK scores with success ratings happened when the LEK questions involved matching fishery species with ecological parameters, such as habitat type, aggregation patterns, depth, and season. Overall, the results suggest that competency in cultural knowledge about fish and fishing has a real effect on success, defined as a pattern of effective performance in the environment in ecological and cultural context (Masten and Coatsworth 1995:21), and that this pattern can be observed and assessed by a fisher's peers.

Evaluation of an Alternative Hypothesis: Are Both Success Ratings and Ecological Knowledge Artifacts of Sociability?

An alternative explanation to the observed relationships between agreement in ecological knowledge and success

Table 7. Correlations Between Average Peer Success Ratings and LEK Scores

Variable	LEK Domain	Correlation Coefficient	P-value
WHERE	Species-habitat matching	0.382	<.025
AGGREG	Aggregation patterns	0.378	<.025
DEPTHFIND	Species-depth matching	0.409	<.01
SEASON	Seasonal abundance	0.279	<.10
CAPGEAR	Gear-species matching	0.172	NS
EKOS	Composite PCA variable	0.538	<.01

could be that both agreement about ecological knowledge and fishers' success reputation are a function of communication between fishers. In this scenario, the more sociable fishers would share more information with other fishers and would be more socially visible, thus more likely to be looked upon positively by their peers. Therefore, the observed patterns in agreement and in peer assessments of success would both be artifacts of a fishers' sociability.

The alternative hypothesis was rejected because no significant correlation existed between peer success ratings and the weekly hours respondents reported spending talking to other fishers ($R = 0.054, p > 0.70$). Furthermore, hours spent talking to other fishers did not exhibit significant correlations with scores in any of the measures of ecological knowledge. Thus, a perceived pattern of effective performance in the environment, independent of sociability, seems to be driving variation in peer assessments of success. As Berto from Santa Isabel said, "We know who the successful fishers are around here. There are not too many of us." Or, in the words of Lydia, a Guayama fisherwoman, "You have to see [fishers] in action to be able to say if they will be successful in fishing. Some of them are good in some aspects of fishing, some of them are better in others. Fishing requires knowledge, *habilidad* (dexterity), and patience, both out in the water and on land."

There is a mechanism, other than social transmission exclusively, that results in agreement in ecological knowledge. As they become experts in finding and capturing fish, fishers learn about the locally relevant environmental and ecological cues and parameters that will guide them to a predictable catch. Over time, expertise and experience in a similar ecological context leads to agreement.

Social and Ecological Complexity Effects on Ecological Knowledge

The socioeconomic context of Puerto Rican small-scale fisheries is characterized by heterogeneity and unpredictability of opportunities for employment and for covering the basic needs of subsistence. The ecosystems that tropical reef-estuarine fishers depend on for making a living are likewise complex and characterized by patchiness and habitat heterogeneity (Almany 2004; Jones and Syms 1998; Polunin, Roberts, and Pauly 1996). Harvestable biomass in estuarine-reef ecosystems is distributed among many species of fish and shellfish (Munro 1984; Polunin, Roberts, and Pauly 1996; Sale 2002). Fishers have adapted to this by using a variety of gear types and by engaging in multiple and complementary forms of fishing, targeting multiple species over space and time (McGoodwin 1990; Pollnac 1998; Ruddle 1994, 1996). Few tropical species, save for some deep water snappers, occur on sufficient numbers to be able to withstand a specialized fishery for a long period of time. Even the deepwater snappers are usually fished as a species assemblage (silk snapper, queen snapper, blackfin snapper, cardinal snapper, and vermillion snapper) rather than as a single species fishery (Suarez-Caabro 1979; Valdés-Pizzini 1985). Intensification of fishing on certain species has resulted in the species becoming rapidly overfished and the object of species-specific regulations (Griffith, Valdés-Pizzini, and García-Quijano 2007).

Attempts to industrialize and modernize Puerto Rican fisheries have generally failed (Pérez 2005). One of the reasons for this is that specialization comes at the expense of flexibility in harvesting strategies. The streamlining of the resource-extractive economy resulting from industrialization and specialization has often resulted in fishery collapses and loss of fishers' livelihoods (Finlayson and McCay 1998; Jacob et al. 2001). The emphasis on flexibility and the ability to harvest a variety of species was an important theme in my interviews and conversations with expert fishers.

Convergence between LEK and Ecosystems Ecology

The last two decades have witnessed increasing convergence between ecosystems ecology and Local or Traditional Ecological Knowledge (Berkes, Colding, and Folke 2000; Berkes et al. 1998; Gagdil et al. 2003; Hunn et al. 2003). Among the most important commonalities between some traditional systems of ecological knowledge and ecosystems ecology are: (1) the emphasis thinking about a unit of analysis that includes abiotic factors of the environment as well as a group or assemblage of interacting biological populations (e.g., a watershed or a landscape) and (2) the embracing of complexity (chaos, non-equilibrium, nonlinearity, unpredictability) as an interesting and even desirable characteristic of ecosystems rather than something to be avoided and or assumed away in explanatory models (Berkes 1999; Berkes et al. 1998; Scoones 1999).

Ecosystems ecology critiques of western science-based, top-down resource management approaches (e.g., Kay et al. 1999) are often very similar to the arguments Puerto Rican fishers use to express their dissatisfaction with resource management by state agencies. Fishers perceive that the state blames them disproportionately for coastal ecosystem degradation while ignoring the effects of other human activities such as coastal deforestation and pollution from coastal industries, tourism development, and urbanization. According to fishers, their being blamed for coastal degradation has resulted in the passing of fishery management plans that are too restrictive for them to be able to adapt to changing fishery conditions. Meanwhile, degradation continues because the real causes are not being adequately addressed (Griffith, Valdés-Pizzini, and García-Quijano 2007). As this article is being written, a large group of Puerto Rican small-scale fishers have declared their intention to create and promote their own fishery regulations code, based on their LEK and experience, as an alternative to the code put forth by the Puerto Rico DRNA (López 2008).

Lázaro, an expert fisher from Patillas, told me that, in his opinion, the main problem with the state's style of fisheries management was that there was a serious discrepancy

between *la ley de la pesca versus la realidad de la pesca* (the laws that govern fishing versus the reality of fishing). According to him, the laws regarding fishing attempt to be so detailed, that they completely miss that coastal ecosystems in Puerto Rico are very complex. In his own words, "a fisher that doesn't have flexibility or room to operate cannot subsist from fishing in these coasts".

Studies of small-scale peasant economies describe how increasing standardization of human activities driven by an authoritarian state may end up compromising the ability of people to make a living and the overall health and resilience of the ecosystem (Scott 1976, 1998; Wolf 1969). For example, Lázaro reports that his favorite kind of fishing is for deep-water snappers, and that, because of the way that the size-limit regulations are enacted, he is forced to be wasteful, which causes him a lot of grief and constrains the time and effort he spends fishing. He added that regulations on deep-water fishing are making it so difficult that many older, knowledgeable fishers have retired, while young fishers are turning into full-time divers, a type of fishing that he views as potentially more destructive, if done carelessly, than deep-water snapper fishing.

Conclusion

Implications for Fisheries Social Science

A long-standing debate in maritime anthropology has been whether fishing success is predominantly affected by technology and modes of production rather than the personal characteristics of fishers such as knowledge and dexterity. (This debate is generally called "the skipper effect debate.") Most studies deconstructing the determinants of fishing success have left "knowledge" as a ghost variable, of unknown magnitude and variability (see Durrenberger 1993; Gatewood 1984; Pálsson and Durrenberger 1982, 1990; Pálsson and Helgason 1999; Poggie 1979; Russell and Alexander 1998). Using sequences of methods such as those used in this research, one can attempt to shed some light on ecological knowledge's effects on success.

Tropical small-scale fishers' goals and cultural models of success in fishing cannot be assumed based on bioeconomic models developed elsewhere, especially the ones developed in temperate fisheries which have very different social and ecosystem dynamics from tropical fisheries (Pauly 1994; Polunin, Roberts, and Pauly 1996; Ruddle 1996). Survival and continuation of the household appear to be the principal economic goals for fishers in this study's region, and their success in their enterprises should be evaluated on their own terms. Assumptions about human behavior that do not take into account worldviews, subsistence strategies, and human institutions often result in predictive failure and subsequent ecological and social disasters and tragedies (North 1993; Scott 1976, 1998).

SE PR fishers demonstrated an understanding that the patterns of productivity of local marine ecosystems are not suitable for a fishery focused on profits or intense short-term exploitation. The knowledge needed to be successful in fishing is geared more to adapting to ecological complexity and the patchiness of fishery resources availability than to focusing on a few economically important species for profitability. This worldview is compatible with a subsistence economy geared towards reducing uncertainty and minimizing the risk of total loss of income rather than towards maximizing the opportunities for profit. Management schemes could build on small-scale fishers' already existent moral economy of household maintenance and subsistence, rather than attempting to curtail flexibility in harvesting and fishing effort (see Griffith, Valdés-Pizzini, and García-Quijano 2007).

To be effective, ecosystem management must address issues at the level of social-ecological systems, addressing issues of quality of life, empowerment, and alternative economic and employment opportunities. Definitions of the fisheries ecosystem as a management unit must include factors that are not usually included in management schemes. Fishing participation, effort, and the harvesting strategies used will depend, to some extent, on the quantity, quality, and dependability of alternative land-based jobs near coastal areas (e.g., Griffith and Valdés-Pizzini 2002). Manuel Valdés-Pizzini (personal communication, 2008) has observed that fishing effort in Southwestern Puerto Rico is to an extent inversely related to job opportunities in the construction, tourism, and services sectors. As part of our involvement with the NOAA and University of Puerto Rico's Coral Reef Ecosystem Studies (CRES), Valdés-Pizzini and I are currently collaborating in modeling fishing effort using insights from ethnographic studies.

For Southeastern Puerto Rican fishers and their families, success is essentially maximizing predictability among complexity and change. In their never-ending quest to achieve success and, thus, the survival of their families, the principal tool, weapon, and credential they have and use is their Local Ecological Knowledge.

Notes

[1]I had originally followed the commonly used Local Ecological Knowledge/Scientific Ecological Knowledge (LEK/SEK) typology. Of the anonymous reviewers for this article, however, brought up an insightful and important point: that the LEK/SEK typology suggests that LEK is by definition not scientific or less scientific than SEK; thus suggested that instead of SEK this article could use "International Science" or "International Ecological Science." Although I agree wholeheartedly with the reviewer's point, for the sake of clarity I decided to keep the more familiar acronym (SEK) while adding "Western" as a preamble to "Scientific Ecological Knowledge" to emphasize that it refers to "Western" Science (thus WSEK). Adopting a common language to talk about local vs. international/academic knowledge remains, however, an important and necessary task for scholars and others who work at the interface between these systems of knowledge.

[2]The 20 expert fishers identified by snowball sampling ranged in age between 33 and 83 years old, with a mean age of 62.3 years old. Their self-reported years of experience fishing ranged from 21 to 79, with a mean of 52.4 years of experience. They represented fishing communities throughout

the region. All of the major types of fishing gear in the study area were represented. As is common for tropical small-scale fisheries, most of the fishers reported having experience engaging in all these types of fishing activity. Eighteen fishers were male and two were female. They mostly fished from locally-made, outboard engine-powered yolas between 14 and 37 feet long (mean 19.6 feet).

It is remarkable that although these fishers represented the regional consensus of the most expert fishers in their communities, only two of them reported that fishing had been their only occupation throughout their lives. In fact, most of them were career part-time fishers and yet were considered expert fishers by their peers. Thus, being a full-time fisher was not a requisite for being considered an expert in fishing. Sixteen key informants grew up in fishing households, and 17 were taught fishing by an older member of their immediate family. The remaining three learned fishing from older fishers who were their neighbors or family friends. Thus, for the most part, their LEK can be assumed to represent a combination of personal experience and inter-generational knowledge.

[3]The structured questionnaire respondents (n=41) ranged in age between 25 and 70 years old, with a mean age of 49.3 years old. Their fishing experience ranged from 7 to 65, with a mean of 37.6 years of experience. All of the coastal municipalities in the study region were represented. As with the key informants, the majority of them (25) learned fishing from their parents or immediate family members, and the rest learned fishing from friends or neighbors. Their outboard-powered yolas measured between 14 and 29 feet long (mean 18.7 feet).

[4]Assumed names are used to protect the key informants' identities.

[5]For a detailed account of how I operationalized and measured variation in success, see García-Quijano (2006).

[6]For similar information about the other fishery species included in the questionnaire, see García-Quijano (2006:182-183).

References

Almany, Glen
2004 Priority Effects of Coral Reef Fish Communities of the Great Barrier Reef. Ecology 85(10):2872-2880.

Aswani, Shankar, and Richard Hamilton
2004 Integrating Indigenous Ecological Knowledge and Customary Sea Tenure with Marine and Social Science for Conservation of Bumphead Parrotfish (Bolbometopon muricatum) in the Roviana Lagoon, Solomon Islands. Environmental Conservation 31(1):69-83.

Aswani, Shankar, and Matthew Lauer
2006 Incorporating Fishermen's Local Knowledge and Behavior into Geographical Information Systems (GIS) for Designing Marine Protected Areas in Oceania. Human Organization 65:81-102.

Berkes, Fikret
1999 Sacred Ecology: Traditional Ecological Knowledge and Resource Management. Philadelphia, Penn.: Taylor and Francis.

Berkes, Fikret, Johan Colding, and Carl Folke
2000 Rediscovery of Traditional Ecological Knowledge as Adaptive Management. Ecological Applications 10(5):1251-1262.

Berkes, Fikret, Mina Kislaliogu, Carl Folke, and Madhav Gadgil
1998 Exploring the Basic Ecological Unit: Ecosystem-like Concepts in Traditional Societies. Ecosystems 1:409-415.

Borgatti, Stephen P.
1996 ANTHROPAC 4.0 Methods Guide. Natick, Mass.: Analytic Technologies.
2001 ANTHROPAC X. Cambridge, Mass.: Analytic Technologies.

Brewer, Devon D.
1995 Cognitive Indicators of Knowledge in Semantic Domains. Journal of Quantitative Anthropology 5:107-128.

Brush, Stephen
1993 Indigenous Knowledge of Biological Resources: The Role of Anthropology. American Anthropologist 95(3):653-686.

Chayanov, Aleksander
1966 Theory of Peasant Economy. New York: Academic Books.

Conservation International
2006 Expedition Discovers Marine Treasures In Netherlands Antilles: New Species of Fish, Seaweeds Found On Caribbean's Saba Bank. Arlington, Va.: Conservation International.

Cordell, John
1974 The Lunar Tide Fishing Cycle in Northeastern Brazil. Ethnology 13:379-392.

Cortés, Jorge, and Marea E. Hatziolos
1999 Status of Coral Reefs of Central America: Pacific and Caribbean Coasts: Status of Coral Reefs of the World: 1998. Townsville, Australia: Australian Institute of Marine Science.

D'Andrade, Roy
1992 Schemas and Motivation. *In* Human Motives and Cultural Models. Roy D'Andrade and Claudia Strauss, eds. Pp. 23-44. New York: Cambridge University Press.

DeWalt, Billie
1994 Using Indigenous Knowledge to Improve Agriculture and Natural Resource Magagement. Human Organization 53:123-131.

Dick, Ronald E.
1996 Subsistence Economies: Freedom From the Marketplace. Society and Natural Resources 9:19-29.

Dietz, James
1986 Economic History of Puerto Rico. Princeton, N.J.: Princeton University Press.

Durrenberger, E. Paul
1993 The Skipper Effect and Folk Models of The Skipper Effect among Mississippi Shrimpers. Human Organization 52:194-202.
1997 Fisheries Management Models: Assumptions and Realities, or Why Shrimpers in Mississippi Are Not Firms. Human Organization 56:158-166.

Fagerstrom, J. A.
1987 The Evolution of Reef Communities. New York: Wiley.

Figueroa, Luis
2005 Sugar, Slavery, and Freedom in Nineteenth-Century Puerto Rico. Chapel Hill: University of North Carolina Press.

Finlayson, Alan, and Bonnie McCay
1998 Crossing the Threshold of Ecosystem Resilience: The Commercial Extinction of Northern Cod. *In* Linking Social and

Ecological Systems: Institutional Learning for Resilience. Carl Folke and Fikret Berkes, eds. Pp. 311-337. Cambridge, United Kingdom: Cambridge University Press.

Forman, Shepard
1967 Cognition and The Catch: The Location of Fishing Spots in a Brazilian Coastal Village. Ethnology 6(4):417-426.

Furlow, Christopher
2003 Comparing Indicators of Knowledge Within and Between Cultural Domains. Field Methods 15(1):51-62.

Gadgil, Madhav, and Fikret Berkes
1991 Traditional Resource Management Systems. Resource Management and Optimization 18:127-141.

Gadgil, Madhav, Per Olsson, Fikret Berkes, and Carl Folke
2003 Exploring the Role of Local Ecological Knowledge for Ecosystem Management: Three Case Studies. *In* Navigating Social-ecological Systems: Building Resilience for Complexity and Change. Fikret Berkes, Johan Colding, and Carl Folke, eds. Pp. 33-52. Cambridge, United Kingdom: Cambridge University Press.

García-Quijano, Carlos G.
2006 Resisting Extinction: The Value of Local Ecological Knowledge for Small-scale Fishers in Southeastern Puerto Rico. Ph.D. dissertation, University of Georgia.
2007 Fishers' Knowledge of Marine Species Assemblages: Bridging Between Scientific and Local Ecological Knowledge in Southeastern Puerto Rico. American Anthropologist 109(3):529-536.

Gatewood, John
1984 Is The Skipper Effect Really a False Ideology? American Ethnologist 11:378-379.

Griffith, David
1985 Women, Remittances, and Reproduction. American Ethnologist 12(4):676-690.
1999 The Estuary's Gift: An Atlantic Coast Cultural Biography. University Park: Pennsylvania State University Press.
2006 Local Knowledge, Multiple Livelihoods, and the Use of Natural and Social Resources in North Carolina. *In* Traditional Ecological Knowledge and Natural Resource Management. Charles R. Menzies, ed. Pp. 153-174. Lincoln: University of Nebraska Press.

Griffith, David, and Manuel Valdés-Pizzini
2002 Fishers at Work, Workers at Sea: A Puerto Rican Journey Through Labor and Refuge. Philadelphia, Penn.: Temple University Press.

Griffith, David, Manuel Valdés-Pizzini, and Carlos García-Quijano
2007 Socioeconomic Profiles of Fishers, Their Communities, and Their Reponses to Marine Protective Measures in Puerto Rico. Miami, Fla.: National Oceanic and Atmospheric Administration, Southeast Fisheries Science Center.

Griffith, David, Manuel Valdés-Pizzini, and Jeffrey Johnson
1992 Injury and Therapy: Semiproletarianization in Puerto Rico's Artisanal Fisheries. American Ethnologist 19(1):53-74.

Guest, Greg
2000 Using Guttman Scaling to Rank Wealth: Integrating Quantitative and Qualitative Data. Field Methods 12(4):346-357.

Handwerker, W. Penn
2002 Construct Validity of Cultures: Cultural Diversity, Culture Theory, and a Method for Ethnography. American Anthropologist 104(1):106-122.

Hunn, Eugene, Darryl Johnson, Priscilla Russell, and Thomas Thronton
2003 Huna Tinglit Traditional Environmental Knowledge, Conservation, and the Management of a "Wilderness" Park. Current Anthropology 44(supp):S79-S103.

Jackson, Jeremy
1991 Adaptation and Diversity of Coral Reefs. Bioscience 41:475-482.

Jacob, Steve, Frank L. Farmer, Michael Jepson, and Charles Adams
2001 Landing and Definition of Fishing Dependent Communities: Potential Social Science Contributions to Meeting National Standard 8. Fisheries 26(10):16-22.

Johannes, Robert E.
1981 Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia. Berkeley: University of California Press.
1998 The Case for Data-less Marine Resource Management: Examples from Tropical Fisheries. Trends in Ecology and Evolution 13(6):243-246.
2001 The Need for the Study of Indigenous Fishers' Knowledge. SPC Traditional Management and Knowledge Information Bulletin 13:28-29.

Johannes, Robert E., Milton M. Freeman, and Richard J. Hamilton
2000 Ignore Fisher's Knowledge and Miss the Boat. Fish and Fisheries 1:257-271.

Johnson, Jeffrey C.
1990 Selecting Ethnographic Informants, vol. 22. Newbury Park, Calif.: Sage Publications.

Johnson, Michael P., Larry G. Mason, and Peter H. Raven
1968 Ecological Parameters and Plant Species Diversity. American Naturalist 102:297-306.

Jones, Geoffrey P., and Craig Syms
1998 Disturbance, Habitat Structure, and the Ecology of Fishes on Coral Reefs. Australian Journal of Ecology 23:287-297.

Kathiresan, K.
2003 How Do Mangrove Forests Induce Sedimentation? Revista de Biología Tropical 51(2):355-360.

Kay, James, Michelle Boyle, Henry Regier, and George Francis
1999 An Ecosystem Approach For Sustainability: Addressing the Challenge of Complexity. Futures 31(7):721-742.

Kempton, Willet, James S. Boster, and Jeniffer A. Hartley
1995 Environmental Values in American Culture. Cambridge, Mass.: MIT Press.

Krushensky, R. D., and Johannes H. Schellekens
2001 Geology of Puerto Rico. *In* Geology, Geochemistry, Geophysics, Mineral Occurrences, and Mineral Resources Assessment for the Commonwealth of Puerto Rico. Walter J. Bawiec, ed. Pp. 10-59. Washington, D.C.: United States Geological Survey.

López, Keila
2008 Crean Frente Común los Pescadores del Litoral Este: Representantes de Villas Pesqueras de la Zona Exigirán Nuevo Reglamento. El Nuevo Día (San Juan, Puerto Rico), February 20.

Masten, Ann S., and J. Douglas Coatsworth
1995 Competence, Resilience, and Psychopathology. *In* Manual of Developmental Psychopathology. Dante Cicchetti, ed. Pp. 715-752. New York: John Wiley and Sons.

McGoodwin, James
1990 Crisis in the World's Fisheries: People, Problems, and Policies. Stanford, Calif.: Stanford University Press.

Menzies, Charles R.
2006 Ecological Knowledge, Subsistence, and Livelihood Practices: The Case of the Pine Mushroom Harvest in Northwestern British Columbia. *In* Traditional Ecological Knowledge and Natural Resource Management. Charles R. Menzies, ed. Pp. 87-106. Lincoln: University of Nebraska Press.

Mora, Camilo
2007 A Clear Human Footprint in The Coral Reefs of the Caribbean. Proceedings of the Royal Society B: Biological Sciences.

Morelock, Jack, Wilson Ramirez, and Maritza Barreto
2002 The World's Coasts. Puerto Rico: Kluwer Press.

Muhr, Thomas
2004 Atlas.ti. Berlin: Scientific Software Development GmbH.

Mumby, Peter J., Alasdair J. Edwards, J. Ernesto Arias-González, Kenyon C. Lindeman, Paul G. Blackwell, Angela Gall, Malgosia I. Gorczynska, Alastair R. Harborne, Claire L. Pescod, Henk Renken, Colette C. C. Wabnitz, and Ghislane Llewellyn
2004 Mangroves Enhance the Biomass of Coral Reef Fish Communities in the Caribbean. Nature 427:533-536.

Munro, John L.
1984 Yields from Coral Reef Fisheries. FISHBYTE 2:13-15.

Nellemann, Christian, Stefan Hain, and Jackie Alder
2008 In Dead Water: Merging of Climate Change with Pollution, Over-Harvest, and Infestations in the World's Fishing Grounds. GRID-Arendal, Norway: United Nations Environment Programme.

North, Douglass
1993 Economic Performance Through Time: 1993 Nobel Prize in Economics Acceptance Lecture. Stockholm: The Bank of Sweden.

Pálsson, Gísli, and E. Paul Durrenberger
1982 To Dream of Fish: The Causes of Icelandic Skippers' Fishing Success. Journal of Anthropological Research 38:227-242.
1990 Systems of Production and Social Discourse: The Skipper Effect Revisited. American Anthropologist 92:130-141.

Pálsson, Gílsi, and Agnar Helgason
1999 Schooling and Skipperhood: The Development of Dexterity. American Anthropologist 101:908-923.

Paolisso, Michael
2002 Blue Crabs and Controversy on the Chesapeake Bay: A Cultural Model for Understanding Watermen's Reasoning about Blue Crab Management. Human Organization 61:226-239.

Pauly, Daniel
1994 On the Sex of Fish and the Gender of Scientists: A Collection of Essays in Fisheries Science, vol. 14. Norwell, Mass: Kluwer Academic Publishers.
2006 Major Trends in Small-scale Marine Fisheries, With Emphasis on Developing Countries, and Some Implications for the Social Sciences. Maritime Studies 4(2):7-22.

Pauly, Daniel, and Jay MacLean
2003 In A Perfect Ocean: The State of Fisheries and Ecosystems in the North Atlantic Ocean. Washington, DC: Island Press.

Pearse, Andrew
1975 The Latin American Peasant. London: Frank Cass.

Peluso, Nancy
1995 Whose Woods Are These?: Counter-mapping Forest Territories in Kalimantan, Indonesia. Antipode 27(4):383-406.

Pérez, Ricardo
2005 The State and Small-scale Fisheries in Puerto Rico. Gainesville: University of Florida Press.

Pinto, Benito
2004 Respiro Momentáneo Para los Pescadores Locales. La Regata: El Periódico Naútico de Puerto Rico 7(4):5.

Poggie, John J.
1979 Small-scale Fishermen's Beliefs About Success and Development: A Puerto Rican Case. Human Organization 38:6-11.

Pollnac, Richard
1998 Social and Cultural Characteristics of Fishing Peoples. Marine Behavior and Physiology 14:23-39.

Polunin, Nicholas, Callum M. Roberts, and Daniel Pauly
1996 Reef Fisheries: Problems and Prospects. *In* Reef Fisheries. Nicholas Polunin and Callum M. Roberts, eds. Pp. 361-377. London: Chapman Hall.

Pomeroy, Robert S.
1992 Management Options for Small-scale Fisheries. The Management of Coral Reef Resource Systems, vol. 44. Manila, Philippines: International Center for Living Aquatic Resources Management.

Posey, Darryl, John Frechione, John Eddins, Luiz Francelino da Silva, Debbie Myers, Diane Case, and Peter MacBeath
1984 Ethnoecology as Applied Anthropology in Amazonian Development. Human Organization 43:95-107.

Romney, A. Kimball
1997 When Does Consensus Indicate Cultural Knowledge? Cognitive Science News 7(1):3-8.

Romney, A. Kimball, Susan C. Weller, and William H. Batchelder
1986 Culture as Consensus: A Theory of Culture and Informant Accuracy. American Anthropologist 88:313-338.

Romney, A. Kimball, William H. Batchhelder, and Susan C. Weller
1987 Recent Applications of Cultural Consensus Theory. American Behavioral Scientist 31(2):163-177.

Ross, Norbert
2004 Culture and Cognition: Implications for Theory and Method. Thousand Oaks, Calif.: Sage Publications.

Ruddle, Kenneth
1994 Local Knowledge in the Folk Management of Fisheries and Coastal Marine Environments. *In* Folk Management in the World's Fisheries: Lessons for Modern Fisheries Management. Christopher Dyer and James McGoodwin, eds. Pp. 161-206. Niwot: University Press of Colorado.
1996 Geography and Human Ecology of Reef Fisheries. *In* Reef Fisheries. Nicholas Polunin and Callum M. Roberts, eds. Pp. 137-160. London: Chapman and Hall.

Russell, Susan D., and Rani T. Alexander
1998 Measuring Seining Strategies and Fishing Success in the Philippines. Human Organization 57:145-158.

Sale, Peter
2002 The Science We Need to Develop for More Effective Management. *In* Coral Reef Fishes: Dynamics and Diversity in a Complex Ecosystem. Peter F. Sale, ed. Pp. 361-376. San Diego: Academic Press.

SAS
2007 JMP 7.0.1. Cary, N.C.: SAS Institute, Inc.

Scoones, Ian
1999 New Ecology and the Social Sciences: What Prospects for a Fruitful Engagement? Annual Review of Anthropology 28:479-507.

Scott, James
1976 The Moral Economy of the Peasant: Rebellion and Subsistence in Southeast Asia. New Haven, Conn.: Yale University Press.
1985 Weapons of the Weak: Everyday Forms of Peasant Resistance. New Haven, Conn.: Yale University Press.
1998 Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed. New Haven, Conn.: Yale University Press.

Simon, Julian
1997 ResamplingStats. Arlington, Va.: ResamplingStats, Inc.

Suarez-Caabro, Jose
1979 El Mar de Puerto Rico: Una Introduccion a las Pesquerias de la Isla. Rio Piedras: Editorial de La Universidad de Puerto Rico.

Valdés-Pizzini, Manuel
1985 Social Relations of Production in Puerto de la Corona: Capitalism and Development in the Puerto Rican Fisheries. Ph.D. dissertation, State University of New York-Stony Brook.
1987 Apuntes Sobre el Desarrollo Histórico de la Pesca en Puerto Rico. Mayaguez, Puerto Rico: UPR Sea Grant College Program Publications.

Vargas Saavedra, Maelo
2004 Pescadores Planean Marcha al Capitolio. Primera Hora (San Juan, Puerto Rico), April 28:21.

Wolf, Eric
1969 Peasant Wars of the Twentieth Century. Englewood Cliffs, N.J.: Basic Books.

Woodroffe, Colin D.
1992 Mangrove Sediments and Geomorphology. *In* Tropical Mangrove Ecosystems. Al Robertson and Daniel Algongi, eds. Pp. 7-41. Washington, D.C.: American Geophysical Union.

Zeller, Dirk, Shawn Booth, and Daniel Pauly
2007 Fisheries Contributions to the Gross Domestic Product: Underestimating Small-scale Fisheries in the Pacific. Marine Resource Economics 21:355-374.