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Navigating over Space and Time: Fishing Effort Allocation and the Development of Customary Norms in an Open-Access Mangrove Estuary in Ecuador

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Abstract:

Fisheries are increasingly understood as complex adaptive systems; but the cultural, behavioral, and cognitive factors that explain spatial and temporal dynamics of fishing effort allocation remain poorly understood. Using Geographic Information Systems (GIS) as a visualization tool, this paper combines catch-per-unit-effort (CPUE) and ethnographic data about the Ecuadorian mangrove cockle fishery to explore patterns in fishing effort and the social production of fishing space. I argue that individual decisions about where, when, and how to fish result in spatial and temporal patterns in effort allocation, ultimately regulating open-access fisheries that typically operate on a first-come, first-serve basis. These emergent patterns in the fishing effort are explained by individual-level preferences and adaptations; the development of knowledge and customary norms through the habitual use of resource space by individuals and groups; ecological conditions; and access. New adaptive challenges threaten to undermine such self-organization of open-access systems on larger spatial and temporal scales prompting a likely re-allocation of the fishing effort in the future.

Keywords: artisanal fisheries, local ecological knowledge, decision-making, complex adaptive systems, Geographic Information Systems (GIS), catch-per-unit-effort (CPUE), Ecuador.

Resumen:

Las pesquerías se entienden cada vez más como sistemas adaptativos complejos; sin embargo los factores culturales, conductuales y cognitivos, que explican la dinámica espacial y temporal de la asignación de esfuerzo pesquero, siguen poco conocidos. Este trabajo, utiliza el Sistema de Información Geográfica (SIG) como herramienta de visualización, y combina la captura por unidad de esfuerzo (CPUE) y los datos etnográficos sobre la pesquería de concha prieta en el Ecuador, a fin de explorar la estructura del esfuerzo pesquero y la producción social del espacio de pesca. Esta investigación sostiene que las decisiones individuales acerca de dónde, cuándo y cómo pescar resultan en patrones espaciales y temporales de la distribución del esfuerzo, en última instancia, que regulan las pesquerías de acceso abierto que normalmente operan en base a, “quien llega primero, se sirve primero.” Estos patrones emergentes en el esfuerzo pesquero se explican por las preferencias y adaptaciones a nivel individual, el desarrollo del conocimiento y las normas consuetudinarias a través del uso habitual del espacio de recursos por los individuos y los grupos, las condiciones ecológicas, y el acceso. Nuevos desafíos adaptativos amenazan con socavar esta regulación interna de los sistemas de acceso libre en las escalas espaciales y temporales más grandes. Esto puede provocar una probable re-asignación del esfuerzo pesquero en el futuro.

Palabras claves: pesca artesanal, conocimiento local ecológico, toma de decisiones, sistemas adaptativos complejos, Sistemas de Información Geográfica (SIG), captura por unidad de esfuerzo (CPUE), Ecuador.

Acknowledgements

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Introduction

Coastal degradation, the decline of marine resources, and a crisis in fisheries management has propelled revisions in fisheries science, which currently seeks to understand human dimensions of environmental change, complexity, and spatial-temporal dynamics of marine resources (St. Martin 2004; Acheson *et al*. 1998; Finlayson and McCay 1998; Wilson *et al*. 2013b; Wilson 2002; Mahon *et al*. 2008; McGoodwin 1990). Moving beyond the simplistic bioeconometric models of conventional fisheries management that assume a predictable relationship between fishers and marine resources, current research incorporates this new focus on spatial and temporal dimensions for marine spatial planning and ecosystem-based management (Kaplan *et al*. 2010; St. Martin 2001; St. Martin *et al*. 2007).[1] A large part of this paradigm shift encourages collaborative learning between scientists and resource users (St. Martin *et al*. 2007), as well as the incorporation of local knowledge (Aswani and Lauer 2006; García-Quijano 2009; Valdés-Pizzini and García-Quijano 2009; Narchi *et al*. 2013; Berkes *et al.* 2000)).

In this more holistic approach to understanding fisheries as complex adaptive systems, the cognitive and behavioral dimensions of fishing effort allocation remain poorly understood and a large source of uncertainty for fisheries management (Hilborn 2007; Teh *et al*. 2012; Fulton *et al*. 2011; Salas and Gaertner 2004; Salas *et al*. 2004; Daw 2008; García-Quijano 2009; Guest 2003; Wilson *et al*. 2013b; Daw *et al.* 2012). Understanding cultural factors influencing fisher decisions about where, why, and when to fish could offer many insights to fishery scientists about how fishers may respond to changes in resource distribution caused by climate change or socio-political factors like the establishment of marine protected areas. As Hilborn (2007: 287) also noted, early work on fisheries focused narrowly on the “optimal” behavior of fishers (Gordon 1954), which makes marine resources susceptible to a tragedy of the commons (Hardin 1968). Anthropologists and other researchers have offered alternative explanations for human-environment interactions drawing upon cross-cultural comparative studies of social organization in non-Western fishing societies (for example, see Johannes 1978; Cordell 1974; Smith 1977; Dyer and McGoodwin 1994; McCay and Acheson 1987). Much previous research on folk management was less concerned with individual decision-making and more intent on providing descriptions about how these traditional systems worked and their potential for self-regulation in the absence of formal mechanisms that aim to control fishing behavior and effort allocation. Recent studies have appropriately drawn attention to the vulnerability of folk management systems in the face of modernity, demographic change, markets, and inappropriate policies (Cinner 2005; Cinner *et al*. 2007; Acheson and Brewer 2003; Dyer and McGoodwin 1994). Other recent research has focused on the emergence of regulatory access controls through a deliberate process of learning, adaptation, and self-organization (Basurto 2005, 2008; Basurto *et al*. 2012) and the effects of changing environments on fishing livelihoods and adaptations (Van Holt 2012; Endter-Wada and Keenan 2005).

While studies of folk management systems have deepened understanding about the relationship between communities and the environment, some researchers have questioned the assumptions about environmental stewardship since social and biological data have only been integrated in a handful of case studies (Berkes 2005; Pollnac and

[1] Both citations for St. Martin provide a more thorough description and critique of bioeconometric modeling and maximum sustainable yield often used in conventional fisheries management.

Johnson 2005). The literature has also generated some debate about whether conservation outcomes in traditional societies are intentional or epiphenomenal (Pollnac and Johnson 2005; Ruttan 1998; Hames 1987). Other researchers have questioned the origins of customary laws and whether they emerged out of a long history of co-evolution between maritime communities and their environments (Dyer and McGoodwin 1994) or if they represent a relatively recent imposition of Western conservationist values (Zerner 1994). As such, Pollnac and Johnson (2005) have suggested that a more vigorous investigation of human-environment interactions is needed to increase the credibility of social science contributions to fisheries science and management.

Studies in human ecology have examined the ways in which territoriality may serve as an informal self-regulating mechanism in fisheries (Acheson 1975; Acheson and Gardner 2004, 2005; Begossi 2006; Begossi 2001; de Castro and Begossi 1996). Like previous anthropological work on territoriality, these theories are spatial in nature and give special attention to the role of resource abundance or scarcity in patterns of exploitation (Cashdan 1992; Dyson-Hudson and Smith 1978). In addition to the ways in which populations of fishers respond to ecological dynamics, these studies have pointed to the ability of fishers to organize collectively, make decisions within technological or economic constraints, or practice avoidance through "niche partitioning" or mutual respect (Nunes *et al*. 2011; Begossi 2001; Acheson 1987). In other words, territoriality often emerges out of cooperative or competitive behaviors of individuals or groups (Acheson and Gardner 2004). Territorial defense has been a key concept in Acheson's work on the Maine lobster fishery, in which the differential productivity of fishing grounds is a result of internal regulation based on fierce rivalry among groups of lobstermen (Acheson 1987; Acheson and Brewer 2003). Others have argued along similar lines that territoriality expressed through secrecy or active defense has been a way of controlling access to marine resources on the high seas (Durrenberger and Palsson 1987). Begossi (2001) has documented less aggressive forms of territoriality based on mutual respect and reciprocity in the Atlantic Forest in Brazil. Others have observed that the division of fishing space is based on "niche partitioning" or the application of different fishing strategies under various technological constraints (Nunes *et al*. 2011; Begossi 2001).

Alternatively, harvesters with relatively equal access to fishing space respond to fluctuating resource abundance through mobility and a series of individual decisions about where to fish. Patch choice and patch time allocation models used in human behavioral ecology have been powerful tools for explaining how decisions are shaped by resource availability, patchiness, and seasonality (Chimello de Oliveira and Begossi 2011; Sosis 2002; Aswani 1998; Thomas 2007). As observed by Sosis (2002), fishers respond to environmental variability and exhibit preferences for patches with the highest profitable returns. They move on to the next most profitable patch when the returns fall below the average. As predicted by optimal foraging theory, fishers alternate fishing grounds based on their knowledge and experience with patch productivity on a previous day (Sosis 2002; Chimello de Oliveira and Begossi 2011).

While patch-choice models suggest some degree of environmental determinism, Sosis's (2002) findings raise interesting questions concerning the social production of fishing space. He notes, despite the high explanatory power of the patch choice model, his data failed to explain why two particular patches of low profitability were exploited.

As also once argued by Cashdan (1983), animal behavioral models often fail to capture the role of culture. Other researchers have argued that preferred resource spaces are based more on perceptions of safety, risk, and costs rather than maximizing catch rates (van Oostenbrugge *et al*. 2004; Teh *et al*. 2012). Moreover, while patch-choice models use individual-level data, the results are often aggregated to explain population trends, thereby obscuring important individual-level cultural nuances and losing an opportunity for individuals to explain their preferences in their own words.

In this paper, I use catch-per-unit-effort (CPUE) data, Geographic Information Systems (GIS), and ethnographic analysis to explore cultural explanations for the patterns in fishing effort allocation in Ecuador's fishery for mangrove cockles (*Anadara tuberculosa* and *A. similis*), bivalve mollusks gathered by artisanal fishers in coastal mangrove forests during low tide periods. In the last ten years, the fishery has experienced harvesting pressures (Mora *et al*. 2009, 2011). Fishing pressure has been further exacerbated by decades of mangrove deforestation associated with the unregulated expansion of shrimp aquaculture and more recent policy changes that have created new common property rights for local fishing associations, which now restrict access to areas once universally enjoyed by all cockle collectors as a public good (Beitl 2012b; Martinez-Alier 2001). This paper is concerned with fishing effort allocation in the remaining open-access areas of the fishery that continue to operate on a first-come, first-serve basis. I use GIS as a tool to visualize the fishing effort over time and space on a micro-scale and ethnographic data to explore how cockle fishers navigate their preferences for particular fishing grounds, and how such preferences develop through daily practice and interaction with the environment. The overall aim is to explain how fishing space is socially produced, adaptive challenges, and the implications for fishery sustainability. Responding to the "spatial turn in fisheries science" (St. Martin 2004), this research addresses a methodological gap in the study of folk systems (Pollnac and Johnson 2005) and contributes to burgeoning interest in how open-access situations do not always result in a tragedy of the commons (Moritz *et al*. 2013).

Study Site

The research reported here was carried out in Isla Costa Rica in the southern province of El Oro, Ecuador (Figure 1). Additional ethnographic information about the cockle fishery was gathered over a period of 21 months between 2006 and 2010 in the provinces of Esmeraldas and El Oro. The study areas have all been significantly affected by the conversion of coastal mangrove forests for shrimp aquaculture since the 1980s. The two study areas in Esmeraldas (Muisne and Las Manchas) have lost about 75% of their original cover, and the Archipelago Jambelí in El Oro has lost over 50% (CLIRSEN-PMRC 2007). Despite the significant levels of habitat degradation over the last several decades, mangrove cockles have maintained significant cultural and economic importance in each of the study areas.

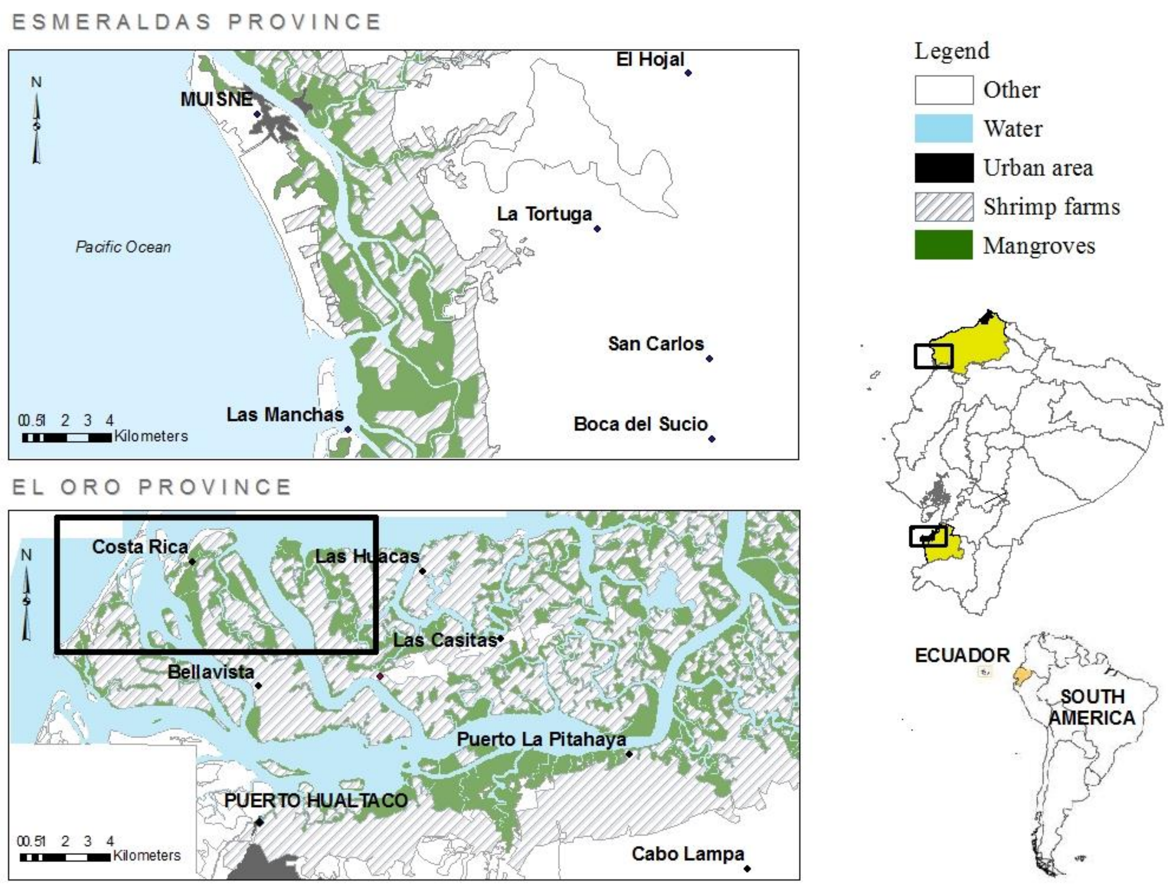

Figure 1. Map of the study areas. This paper draws on ethnographic research conducted in the provinces of El Oro and Esmeraldas. Isla Costa Rica is the main study area for the analysis of the fishing effort over time and space.

While all mangroves in Ecuador are considered government domain, artisanal fishers have ancestrally enjoyed usufruct rights to harvest resources from them. However, over the last several decades, shrimp farmers have exercised their political and economic power to exploit loopholes in laws, poor monitoring, and confusing jurisdictions of the coastal zone. These factors have resulted in the unregulated expansion of the shrimp industry over several decades. In the year 2000, the government began granting ten-year mangrove concessions called *custodias* to local fishing associations for community-based stewardship and sustainable use (Bravo 2007). To date, about 38,000 hectares of mangroves have been allocated to 41 community associations (Rosero Moya and Santillan Salas 2011).

Isla Costa Rica is located on the outer edge of the Archipelago Jambelí in El Oro Province, a landscape dominated by shrimp farms and a complex estuarine system fringed with mangrove stands. Located about 45 minutes in motor-powered boat from the Port of Hualtaco and another 15 minutes by bus from the city of Huaquillas on the Peruvian border, Isla Costa Rica's 300 inhabitants depend primarily on mangrove

resources for their livelihoods. Like other communities in El Oro, men and boys have traditionally harvested cockles for subsistence and markets (INP 1971), in contrast to Esmeraldas Province where, until recently, cockle collecting has been predominantly associated with women and children (Ocampo-Thomason 2006; Mera Orcés 1999). Some families practice cockle mariculture by storing small shells below the market size in mangrove enclosures located directly in front of their homes. There are two local fishing associations. One, whose constituents are primarily cockle collectors and their wives, is in charge of a *custodia.*

As one of the first recipients of a *custodia*, the Asociación Isla Costa Rica has successfully managed their 519 hectare concession since the year 2000 (Bravo and Altamirano 2006; Beitl 2011). As such, Isla Costa Rica reflects a mixed property system, in which all four property arrangements highlighted in the commons literature are present (see Ostrom *et al*. 1999): 1) public/ government (all mangrove, beach, and waterways); 2) private (shrimp farm concessions); 3) common property (*custodia* of the Association Isla Costa Rica); and 4) open-access (all gathering grounds outside the *custodia* shared with fishers from adjacent communities) (Figure 2).

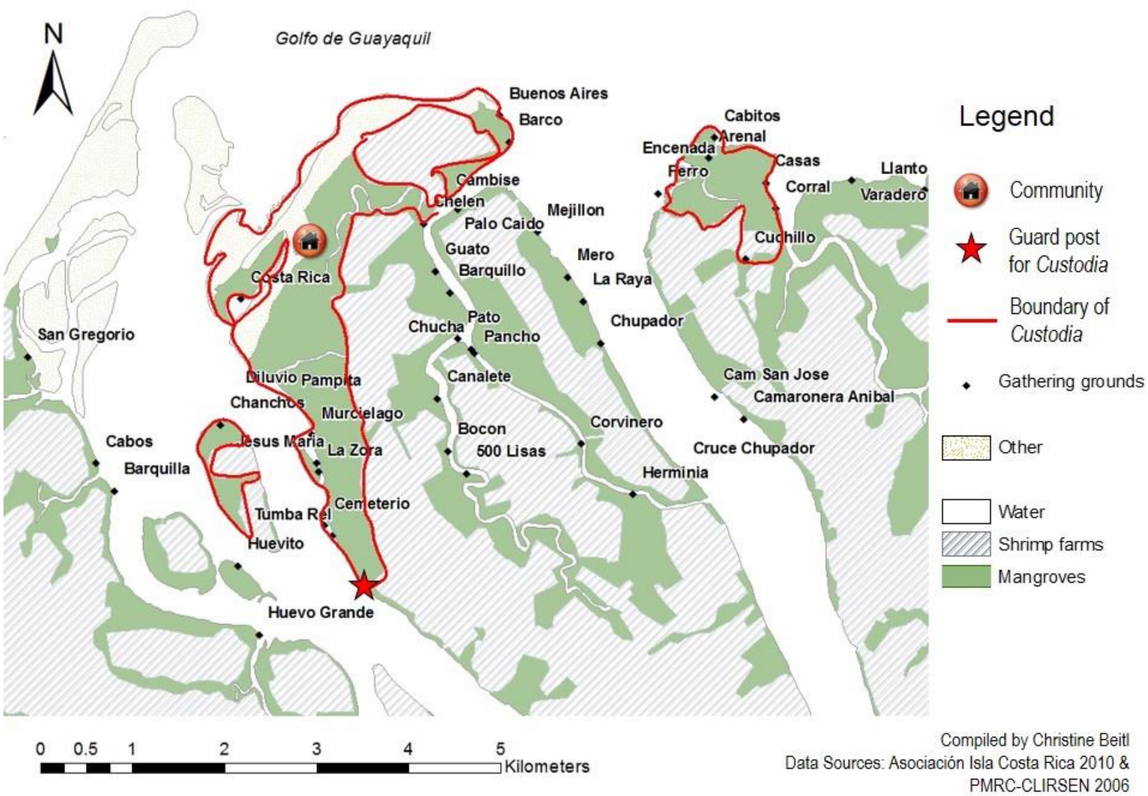

Figure 2: Mixed "property" arrangements include: 1) Government (mangrove, beach, and waterways); 2) private (shrimp farm concessions); 3) common property (fishery areas within a community concession utilized exclusively by residents of Isla Costa Rica; 4) open-access (all fishery areas not delineated by the boundaries of a concession by which all fishers share usufruct rights).

Based on local ecological knowledge, experience with the productivity of fishing grounds, as well as biological knowledge presented in workshops by external organizations, the association has designated certain cockle beds within their *custodia* for periodic closures: Chanchos, Diluvio, Costa Rica, Cemeterio, Jesus Maria, and Manoas. Other parts of the *custodia* and open-access areas are harvested daily. The fishery-managed areas are harvested for ten days after 30-day closure periods, with the exception of Manoas harvested every Saturday. The managed areas function much like the common property regimes described by Ostrom (1990) with locally designed rules, monitoring, sanctioning, and a rotating guard system by members of the association to prevent access by outsiders (Beitl 2011).[2] During the early years, the Asociación Isla Costa Rica actively defended its *custodia* against cockle collectors from Puerto Hualtaco most likely harvesting their own ancestral gathering grounds around the neighboring community of San Gregorio, which was abandoned in the 1950s due to subsidence. Today, fishers from Hualtaco and Isla Costa Rica share open-access space. While many cockle collectors from Hualtaco respect the boundaries of Isla Costa Rica's *custodia*, they continue to occasionally face violent confrontations with the proprietors of other newly established concessions throughout the archipelago (Beitl 2012b).

Methods

The micro-scale analysis of fishing effort allocation in Isla Costa Rica draws on CPUE data gathered by the association from January 15 to June 30, 2010 as part of our agreement for a community monitoring project.[3] Similar to the concept of "return rates" used in optimal foraging theory for its ability to estimate relative resource abundance (Aswani 1998), CPUE is a measure of the density of the population size of a target species used by fishery scientists to assess stocks. According to the National Oceanic and Atmospheric Administration, "large CPUEs indicate large populations since many individuals are caught for every unit of fishing effort" (NOAA n.d.). The National Fisheries Institute (INP) in Ecuador, a public research institution, defines CPUE as the average number of shells per unit of effort, where each unit of effort refers to each fisher's trip.

To document and explore preferences in fishing space, we began with exploratory fisher diaries (n=10). From March to April 2009, each participant kept a daily record of the number of shells and names of the sites, among other information. These preliminary results were shared and discussed in two separate focus groups to gain understanding about who decides to go where and why. The exploratory diaries and focus groups also provided substantial background information that aided in the design of a semi-structured interview questionnaire (Weller and Romney 1988; Johnson 1998), which was administered in all four study areas. Using an Etrex Vista Global Positioning System (GPS) we mapped the location of the gathering grounds during high tide.[4] The map was later verified by the ten fisher diary participants.

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[2] For a more detailed description of characteristics of common property regimes, see Ostrom (1990).

[3] Per our agreement, these data are now the intellectual property of the Asociación Costa Rica and future research using this dataset should note the appropriate citation (Asociación de Mariscadores Pescadores Artesanales y Afines "Costa Rica" 2010).

[4] All points were marked at the entrance to small creeks more accessible by motor-powered boat during high tide.

The idea for the community monitoring project grew out of conversations with Adolfo Cruz, the president of the association (Beitl and Cruz 2010). One field assistant collected daily CPUE data from 27 participants over 166 days (excluding Sundays and holidays), resulting in 2,160 observations from 60 different gathering grounds. The participants included members of the association, their sons, and two members from the island's other fishing association, representing about half of the estimated number of cockle fishers in the village. Participants provided information about the site of extraction, CPUE, the number of hours worked, number of shells used for personal consumption or mariculture, number left in the mangrove, the number sold, and their alternative activity if they did not go cockle collecting. In addition to CPUE data, the field assistant documented the total fishing effort each day by counting the number of fishermen from March to June.

I entered all the CPUE data into an Excel spreadsheet and exported it to SPSS 17.0 for cross-tabulation of fisher by fishing ground to create a pivot table. The table was joined with GPS points in GIS to create a new layer file capable of depicting the intensity of individual effort by site over time. To further prepare the data for analysis, I divided the fishing grounds into four major zones (Figure 2): 1) sites around San Gregorio (Zone 1); 2) sites around Chelén Estuary often referred to as "*aquí atrás*" or "right here behind" the community (Zone 2); 3) the area of the *custodia* harvested on a daily basis called *Sector Corazones* (Zone 3); and 4) the fishery-managed areas of the *custodia* harvested for ten days after 30-day closure periods. I used analysis of variance tests (ANOVA) to compare differences in CPUE between the four zones.

The ethnographic analysis draws on semi-structured interviews (n=146), observations, participant observation, and focus groups (n=7) in all four study areas. In Isla Costa Rica, field assistants and key informants often helped with participant recruitment (n=58).[5] In Puerto Hualtaco, cockle buyers, field assistants, and occasionally INP biologists helped randomly select individuals as they disembarked from the boats returning from fishing trips as the tide was rising (n=33).[6] In Muisne, my field assistant and I randomly recruited informants from our boat in the middle of the estuary at the end of the low tide period, offering refreshments and to tow people's canoes into port in exchange for their participation (n=47). In the village of Las Manchas, my field assistant and I recruited informants during five separate visits (n=8). The general questionnaire was divided into four sections including 1) information about the catch, fishing grounds, and activity of cockle collecting; 2) baseline demographic information; 3) perceptions about change in mangroves and the cockle fishery; and 4) participation in civil society, collective action, and other livelihood strategies (see Beitl 2012a). Two questions from the general questionnaire were particularly relevant for this portion of the research: the name of each informant's favorite gathering ground(s) and reasons for their preference(s). In each of the focus groups (n=7), three to 25 participants helped me further understand how people choose certain fishing areas. Moreover, I gained much understanding by participant observation in cockle collecting in all four study areas. The ethnographic data were used to interpret and contextualize the spatial patterns in the fishing effort revealed by GIS.

[5] 23 of those 58 interviewees also participated in the community monitoring project.
[6] Out of the 36 recruited in Puerto Hualtaco, only three declined to participate.

Results

Table 1 registers the names of the 60 gathering grounds divided into four zones in Isla Costa Rica. The table includes information about average CPUE at each site, total number of trips (fishing effort), distance from the community, and the number of times that site was cited in an interview as "preferred" by cockle fishers from Isla Costa Rica and Hualtaco. The mean catch is 79 shells per unit of effort (n=2,160) with significant differences between the four zones (ANOVA: $F = 35.90$; $df = 3$; $p = 0.000$; $n = 2,146$).[7] Encenada (Zone 3) is the most popular site with the highest frequency of trips, followed by three gathering grounds in the managed areas of the *custodia*, and finally, San Gregorio (Zone 1). The most frequented site in Zone 2 is Chelén. Interestingly, less popular sites in Zone 2 along the Chupadores Estuary were cited as preferred spots by about one-third of the cockle fishers interviewed in Hualtaco (n=33).

Table 1. Names and characteristics of all gathering grounds frequented by residents of Isla Costa Rica from Jan – Jun 2010.

GATHERING GROUNDS	Mean CPUE (number of shells per unit of fishing effort, or trip)		Total Number of Trips	Distance from Community (km)	Number of times cited in interviews as "preferred"
	Mean CPUE	Std. Deviation			
Grounds in Zone 1: Areas around San Gregorio					
Barquillo	69	41.89	5	2.533	1 (CR), 1(H)
Cabos	63	10.79	7	2.404	1 (CR)
Huevito	71	24.55	77	2.896	2 (CR)
San Gregorio	71	23.67	146	2.407	4 (CR), 1 (H)
Silverio *	118	60.1	2		
Total Zone 1	71	24.64	237		
Grounds in Zone 2: Areas near the Community and "Aquí Atrás"					
Buenos Aires	62	7.21	3	3.476	
Cambise	77	43.78	18	2.531	1 (CR)
Canalete	63	17.31	21	2.4	
Canto *	57	19.57	30		
Canton *	45	21.21	2		
Chelen	58	25.46	71	2.164	3 (CR)
Chucha	97	12.37	7	2.558	
Chupadores	53	26.3	4	3.949	3 (CR), 13 (H)
Cruce Chupador	110	.	1	5.183	
Guato	77	27.19	61	2.13	1 (CR)
Juanillos *	50	14.14	2		1 (CR)
La Zora	60	17.32	3	2.084	
Manoas	65	21.56	45	0.964	
Mejillon	40	14.14	2	3.292	
Mero	87	23.83	7	3.566	

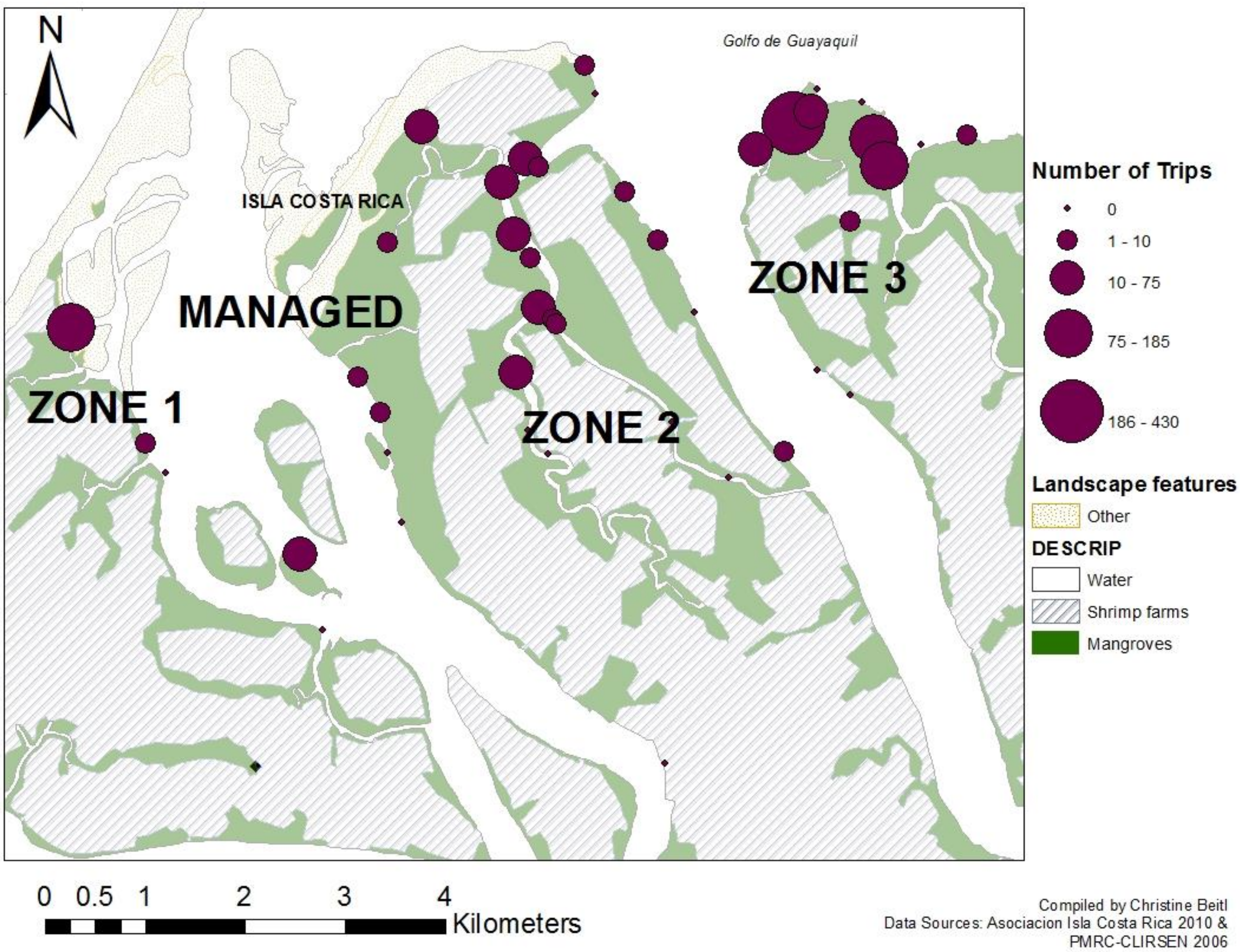
[7] Note that trips with incomplete information were dropped from the analysis of CPUE by zone.

Murcielago	80	.	1	1.683	
Palo Caido	48	18.11	8	2.532	
Pancho *	74	35.27	6	2.614	
Pato	63	33.18	31	2.405	
Raya	75	.	1	3.705	
Tumba Rel	115	49.5	2	2.791	
Vial *	100	.	1	0.89	
500 Lisas				3.136	1 (CR), 1(H)
Pampita *	78	.	1	1.274	1 (CR)
Piedredo *	145	.	1		
Sango *	101	20.51	2		
Sanja *	75	.	1		
Sortija *	28	.	1		
Vacon *	82	.	1		
Total Zone 2	67	28.59	330		
Grounds in Zone 3: "Sector Corazones"					
Arenal	80	21.07	44	5.331	
Casas	81	22.87	143	5.864	5 (CR)
Corral	84	24.17	95	5.908	2 (CR)
Cruce de Corazones	149	68.49	5	5.964	6 (CR)
Cuchillo	100	.	1	5.196	2 (CR)
Encenada	79	27.71	451	5.149	16 (CR)
Pato Corazones *	63	30.55	3		
Peligro	75	.	1		
Perro	79	32.38	21	4.689	2 (CR)
Varadero	225	.	1	6.916	
Ballena				6.781	2 (CR)
Cogollo *	48	3.54	2		
Desague *	75	.	1		
Lagarto *	80	.	1		
Llanto	150	.	1	7.538	1 (CR), 1(H)
Total Zone 3	81	27.6	770		
Fishery-Managed Areas of the Custodia					
Cemeterio	111	38.19	22	2.646	
Chanchos	100	34.7	330	1.396	1 (CR)
Costa Rica	72	27.19	178	0.1619	
Diluvio	74	27.02	270	1.223	1 (CR)
Jesus Maria	75	26.71	10	1.981	
Total Managed Areas	85	33.64	810		
Unknown Locations					
Cruce *	103	16.43	5		
El Cruce *	65	25	3		
Gabino *	140	.	1		
Toldo *	80	.	1		
Marranco *					1 (CR)
Total (all sites)	**79**	**31.15**	**2160**		

Caption: * Table includes: average catch-per-unit effort (CPUE) and fishing effort (total trips), distance from community, and the number of times each site was mentioned as a preferred spot during the interviews in Isla Costa Rica (CR, n=58) and Hualtaco (H, n=33). * denotes the coordinates were not mapped with a GPS.

Figure 3 depicts aggregations of fishing effort allocation during two phases, illustrating the movement of fishers in response to rules of their common property arrangements. Figure 3a depicts the closure periods for managed areas and Figure 3b illustrates the open periods. The larger circles indicate a higher number of fishing trips. Figure 3a further suggests that fishing effort is higher in Zone 3, an area also associated with a higher CPUE (Table 1).

3a.



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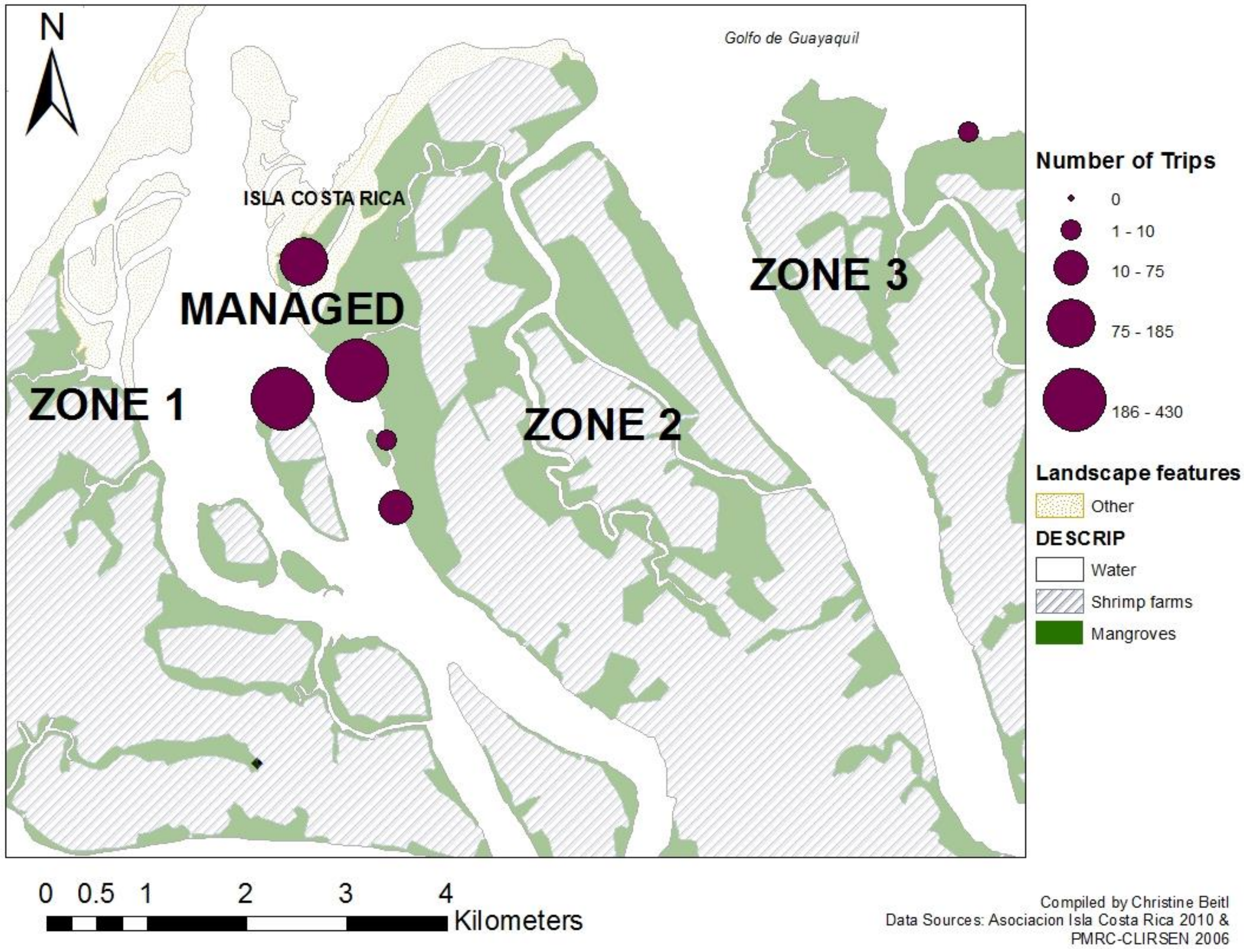

Figure 3. Fishing effort allocation over space during two phases: a) closure periods of the managed area; b) open periods of the managed area.

Figure 4 graphically illustrates the relationship between fishing effort (number of trips) and catch-per-unit-effort (CPUE). The figure shows that despite the high number of fishing trips to Zone 3 and the managed areas, a relatively stable harvest of shells per person is maintained across all sites. However, the average CPUE is slightly higher in these two zones compared with Zones 1 and 2 with statistically significant differences (Table 1). This relationship between effort and CPUE suggests that Zone 3 (like the managed areas) is more productive and able to withstand a higher fishing effort than the other two zones. However, like Figure 3, this figure also fails to explain why less productive areas in Zones 1 and 2 are harvested and by whom.

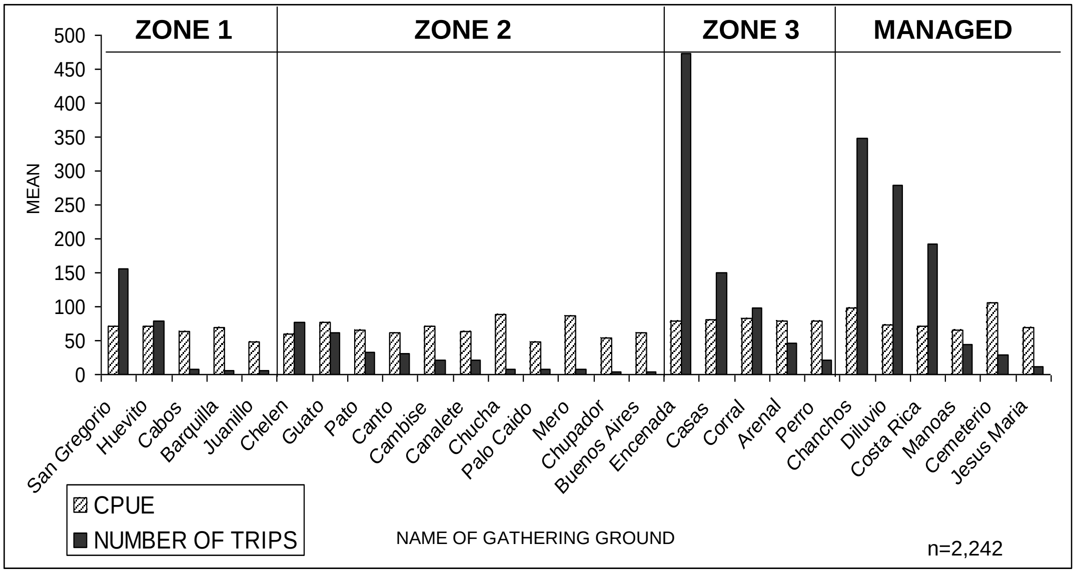

Figure 4. Relationship between fishing effort and CPUE in Isla Costa Rica. * Note that only the most popular sites with three or more trips are presented.

Figure 5 shows the fishing effort allocation by individuals, illustrating that certain fishers habitually harvest from the same zones, even if they are not the most productive (Figure 5). Each individual was color-coded in three primary colors according to his apparent "preference" from the data (or zone associated with his highest frequency of trips over time). These apparent preferences for certain areas correlated with their stated preferences in interviews (n=20). The 13 fishers with the highest frequency of trips to Zone 3 were coded blue; the four who prefer Zone 2 were coded red; and one who preferred Zone 1 was coded yellow. Individuals who harvest from two or more zones with relatively equal frequencies were coded their respective secondary colors, orange (Zones 1 and 2), green (Zones 1 and 3), and purple (Zones 2 and 3). The three people who harvest managed areas almost exclusively were coded white. To explain these apparent preferences, the following sections turn to the ethnographic data.

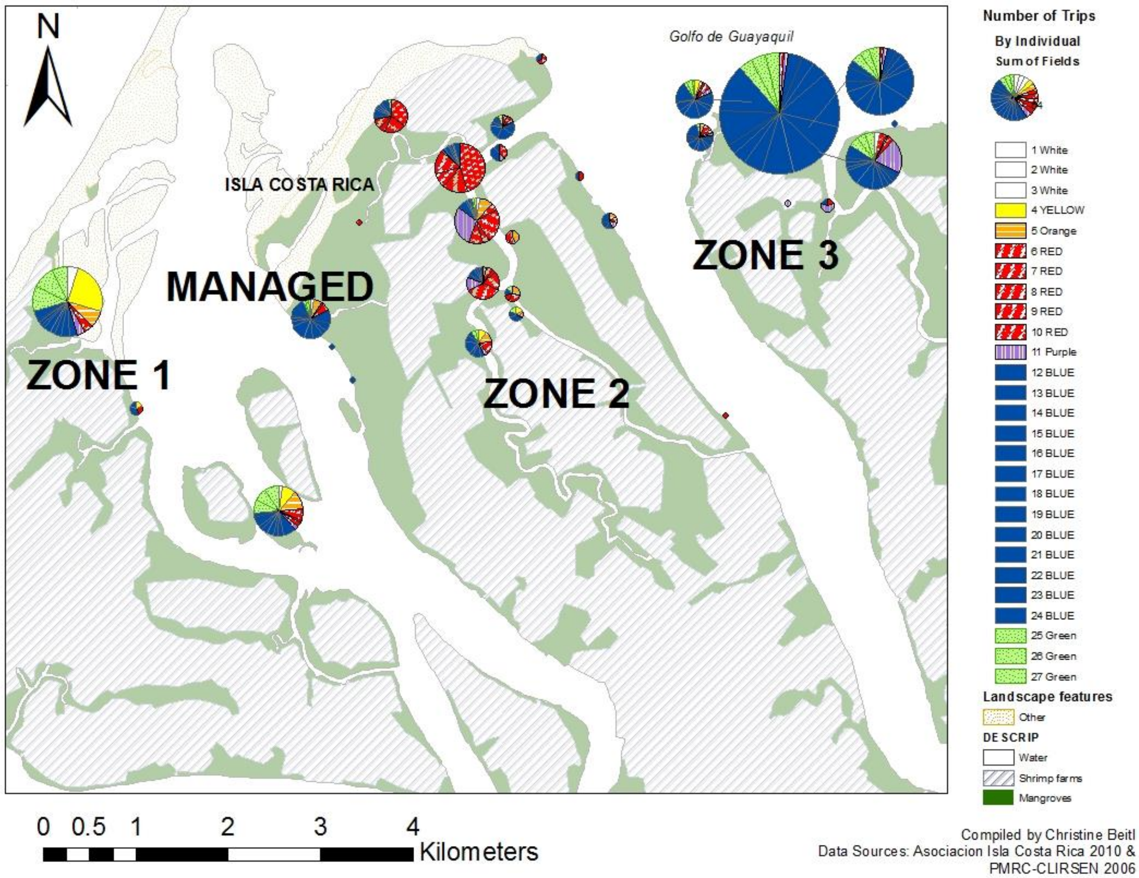

Figure 5: Individual differentiation in fishing effort allocation over space from Jan – Jun 2010

Since preferences for resource space are not unique to Isla Costa Rica, Table 2 summarizes responses from interviews in all four study areas. Free responses were coded and quantified in the table. The categories are not mutually exclusive since the questions were open-ended. Common reasons included: “more shells” (n=41), “bigger shells” (n=22), or “closer” (n=15). When I left the question more open-ended, some people responded similarly, but other explanations emerged, such as, “*estoy enseñado*” or “I am used to going there” or “*allí cojo,”* or literally “that’s (the spot) I get.” I also heard “it’s my area” and “it’s where I always get shells.” A cockle collector from Muisne summed up what I heard from many others: “*todos cogen su rutina*” or “everyone makes their own routine.” Those who did not have specific reasons for frequenting certain gathering grounds suggested they go wherever the boat takes them alone, with their family, or group of friends. The 10% (n=146) that did not have favorite spots typically responded this way—that “all the gathering grounds are the same.” Further discussions during the focus groups revealed other insights into how these customary norms may have developed over time. Some people commented on ecological conditions and how they typically avoid areas where the mud is too soft or too hard. Others expressed their knowledge about the relationship between shell size and ecological conditions (i.e. small shells from soft mud and larger shells from harder substrate, or in the *préstamos* along shrimp pond walls).

Table 2. Response categories explaining site preferences from interviews (n=146).

Response category	Number	Explanation
More shells	41	More shells. One can harvest them faster and return home quicker.
Bigger Shells	22	Bigger shells. Some explained the reason for this is because there is less competition in these areas.
"Enseñado"	19	“That's where I always go" or "that's my area" or "that's where everyone goes." They have been going there since childhood and it was where their relatives, friends, or "their ancestors" showed them.
Closer	15	Those who liked to work close to home did not like paying for the trip (usually $1-2 depending on the distance).
Boat brings us there	14	"That's where we always go" (Isla Costa Rica) or "wherever they take me" (Puerto Hualtaco).
Preferred sites not viable	13	Preferred gathering grounds were no longer viable or accessible because of shrimp farms, *custodias,* too much competition, or overexploitation.
Ecological reason	9	Includes explanations like, "larger areas" or "better habitat for cockles" or they find the substrate easier gather shells quickly.
Company	6	Depends. They go wherever the others go.
No reason	4	Did not know why they preferred the areas they cited.
Safer	1	(Isla Costa Rica) Safer from piracy or other malicious people.
Other	4	"I like to go where few others go" or "few outsiders."
No preference	13	“All sites are the same” and they go "everywhere," "different places," or "wherever they take me." "We alternate among cockle beds depending on the tidal period." "You go to your site and search for cockles. If someone else is already there, you move on."

Caption: * Note categories are not mutually exclusive.

Discussion

Collecting Cockles in the Mangrove Margins

In a day’s work, many cockle fishers secure their rubber boots and gloves, bundle their bodies and heads in clothing, and arm themselves with mosquito repellent to protect against the hot sun or cold rain and wind, aggressive insects, biting snakes, and stinging fish that burrow in the mud. A net bag called a *jicra* is used in El Oro to gather the shells while in Muisne, cockle collectors use anything from traditional gathering baskets to buckets, plastic bags, half soda bottles, their pockets, or their boots. The *faena* (work

period) usually lasts about three hours for most, but many cockle collectors work until they "*completar*," or reach a rounded number of 25, 50, or 100 shells, depending on their goal for the day, level of skill, and luck. After finding a suitable patch and enduring a crouched position as they weave through a thicket of low-lying branches, maneuvering over and around the prop roots, or sinking in thigh-deep mud, the collector will have gathered anywhere between five to 250 shells that sell for $7-22 per 100 shells, depending on the province. In El Oro, cockles sell for $12-22/100 depending on quality (size of shells). In Esmeraldas, shells sell for $7-12/100. Prices increase when demand is highest during Easter and Christmas holidays when Ecuadorians flock to the beaches and demand traditional coastal cuisine.

Tides play a key role in decisions about where and when to fish, and for how long. In Isla Costa Rica, gill-net fishing is usually done during high tides and cockle collecting during low tides. Some men do both activities while others are dedicated exclusively to cockle collecting. As one man commented, "our whole way of life here on the island is dictated by the tides."[8] Spring tides (full moon) and neap tides (new moon) alternate on a cycle of eight-day periods. The larger swell of spring tides is associated with a longer lag time between rising and falling tides. This allows collectors to reach areas normally submerged during neap tides or travel further out into areas with less harvesting pressure. The lunar cycle and tidal periods also influence decisions about cockle collecting in Esmeraldas. People in Muisne refer to spring tides as "*agua buena*," or "good water," and neap tides as "*agua mala*," or "bad water" when many cockle collectors decide to stay home or dedicate their time to other livelihood strategies. Those who decide to collect cockles during the shorter "*agua mala"* period usually stay close to the community.

In addition to the lunar cycle and tidal periods, seasonal cockle collecting and daily fluctuations in the fishing effort might also reflect conditions of the broader economic context. The increase in prices during holidays provides incentives for part-time cockle collectors who typically prefer other livelihood strategies. Some researchers have noted that the cockle fishery may be a last resort when other jobs are not available (Ocampo-Thomason 2006; Velásquez Runk *et al*. 2007). Others have asserted a social stigma is associated with cockle collecting in Ecuador (Kuhl and Sheridan 2009). However, for many cockle fishers, it is a resource that can be harvested year-round with reliable returns, thereby ensuring more income security than other small-scale fisheries that require investments in gear or specialized knowledge. Similar to other studies of fishermen (McGoodwin 1990; Griffith and Valdés Pizzini 2002), many cockle collectors in Ecuador prefer the freedom of fishing and collecting cockles over being "peons" in wage-labor positions. For some, particularly in the smaller communities and among members of local fishing associations, there is a great sense of pride and job satisfaction.

Division of Space: Territoriality *versus* Mutual Respect

Throughout much of the Ecuadorian coast, the mangrove cockle fishery is open-access operating on a first-come, first-serve basis. The social division of space in the open-access areas around Isla Costa Rica reflects an informal system of mutual respect among members of the community and outsiders from Hualtaco, similar to other small-scale fisheries in Mexico (McGoodwin 1994) and the Atlantic Forest in Brazil (Begossi

[8] All quotations are my translations from Spanish.

1995; Begossi 2001). For example, despite their proximity to the community, certain cockle beds in Zone 2 were cited as preferred spots by people in Hualtaco and frequented less by collectors in Isla Costa Rica (see Table 1). One explanation for this mutual respect is that many fishers in Hualtaco are distant relatives whose families have migrated to the port in the last 50 years. This social system of cordial relations among fishers from different communities is further maintained through membership of many local associations to larger provincial and national federations of fishing associations. For example, when the Asociación Isla Costa Rica celebrated their ten-year anniversary during my residency in November of 2009, they invited several associations from Hualtaco, friends and relatives from neighboring communities, and employees on local shrimp farms to join in the festivities consisting of soccer matches by day and dancing, eating, and drinking into the night.

On the other hand, many cockle collectors from Hualtaco and Isla Costa Rica reported defensive behavior among fishers in the community of Las Huacas (adjacent to Isla Costa Rica), similar to territoriality in Maine's lobster fishery (Acheson 1987, 1975). Stories abound about violent confrontations with fishers from Las Huacas often described as "mean" and "criminal-like." Men from Las Huacas are infamous for beating those who trespass into their areas; they confiscate their catches and sometimes steal their personal belongings like *jicras,* caps, money, wristwatches, or jewelry. Informants in Muisne also relayed similar accounts of confrontations with people from Las Manchas who have a reputation of threatening outsiders with machetes, a claim the people from Las Manchas do not deny. However, territorial behavior may be unique to only certain communities and not generalizable to the entire Ecuadorian cockle fishery. For the most part, cockle collectors in Ecuador are non-confrontational and with the exception of the new *custodias,* the fishery is characterized as a free-for-all in which fishing space is divided among individuals who are *enseñados* to their customary grounds. For example, if a cockle collector arrives at a site that someone else has gotten first, he might feel agitated, but there is not much he can do other than simply accept it and think to himself, "*me ganó el puesto*" or "he beat me to it" before moving on to a different area.

Becoming *Enseñado:* The Social Production of Fishing Space

This research shows that a higher fishing effort correlates with a higher CPUE, consistent with the predictions of optimal foraging theories and patch time allocation models (Sosis 2002; Chimello de Oliveira and Begossi 2011; Aswani 1998; Thomas 2007). However, further analysis of individual differentiation over the same space reveals that the same set of individuals habitually harvest less productive areas as spaces they have claimed as "their own." These findings signal that not all fishers are driven by optimizing tendencies, as also suggested by other researchers (Guest 2003; van Oostenbrugge *et al*. 2004; Teh *et al*. 2012). In contrast, preferences for less productive spots have been shaped by habitual use and the development of intimate knowledge about certain areas. In other words, habit, traditions, kinship and friendship networks, the organization of labor, access, and ecological reasons other than actual CPUE influence decisions about where to fish in the Ecuadorian cockle fishery. The notion of being "*ensenado"* or "used to" certain areas explains not only why less productive cockle beds are harvested, but also why those areas are harvested by the same individuals every time.

People become habituated to certain areas for several reasons. The most common explanation is that one becomes *enseñado* after harvesting the same grounds for many years. As many cockle collectors in all four study areas explained, "it's where I (or we) have always gone" or "that's where everyone goes." Sometimes a fisher may claim to have discovered those areas on his own, but more often, fishers explain they have long harvested those areas in the footsteps of their forefathers, parents, grandparents, other relatives, or a friends with whom they most prefer to fish. In Isla Costa Rica, the mangrove areas in Zone 3 are described as "more extensive" and a "better habitat" (for cockles), even though the shells may be smaller in size. By comparison, other extensive mangrove areas in Zone 2 are dominated by mangrove crabs (*Ucides occidentales*), which few fishers in Isla Costa Rica harvest for market. Thus, cockle beds in Zone 3 are perceived as more abundant and productive, "constant and secure," and "far enough from the port that there is less competition" with outsiders. Similar to Basurto's (2008) observations, these perceptions guide individuals in their daily decisions and interactions with fishery resources. Furthermore, since Zone 3 is officially part of the association's *custodia*, many people from Hualtaco respect the boundaries. People from Isla Costa Rica say that their forefathers have always harvested Zone 3, which allowed them to incorporate these areas into their legal *custodia* during their negotiations with the government in 2000.

Another way one becomes *enseñado* is through regular use as they follow their friends and family or join the passenger boat in a daily routine. Boat captains in Isla Costa Rica carry groups of 10-15 cockle collectors to Zone 3, which is another reason why the fishing effort is significantly higher than sites closer to the community. The cost of the trip is $1-2 and a few people prefer not to pay and instead travel on foot to sites nearer the community. Some collectors prefer to work alone "without the distraction of conversation" thereby avoiding the larger groups who travel together to their respective gathering grounds. When I asked people who predominantly harvest shells from Zone 2, they commented that "only a few of us know those areas" and "I know those areas," which allows them to harvest successfully. It is not clear whether people become *enseñado* to certain areas because of their actual success or whether the perception of success grows out of the process of becoming *enseñado*. What is clear is that very few cockle collectors in all four study areas say that they have no preference at all.

Knowledge, Timing, Rotation, and Fishery Sustainability

The implication of becoming *enseñado* is that fishers gain intimate knowledge about their areas: the locations of the best spots, when they were harvested last, who else is harvesting them and how often, and whether the others harvest in a sustainable manner. Since the direction of the relationship between knowledge and perceptions of success is not clear, resource space preferences may be partially explained by Bourdieu's notion of *habitus*, or the everyday practice of individuals by which knowledge is encoded in both cognitive and behavioral interactions with social and biophysical structures of the external world (Bourdieu 1977: 78-87). In other words, the dynamic production and reproduction of local ecological knowledge is reinforced through reciprocal feedback between knowledge and action in everyday practice.

Rotation of cockle beds is key to fishery productivity and stability. Many collectors alternate among a set of preferred spots to which they are *enseñado*. According

to customary knowledge, two weeks is sufficient time for a cockle bed to regenerate a supply of shells for the next harvest, illustrating also the importance of the lunar cycle as a guide for timing the rotation, as observed by other ethnographers in Brazil (Cordell 1974). With each harvest, small shells are often left behind to promote propagation and spawning. Over generations, this local knowledge is passed down from one generation to the next and often reinforced in workshops sponsored by biologists from NGOs and government organizations. The fishery-managed areas of the *custodia* represent an institutionalized effort to regulate rotation among cockle beds to ensure sustainability. During the ten-day open period, the other cockle beds are given time to recuperate. Because of their perceived productivity, many fishers abandon their other livelihood activities to harvest almost exclusively from the managed areas, resulting in a higher effort allocation than all the other zones. On the other hand, the managed areas are able to withstand a higher fishing effort than open-access areas (Beitl 2011).

Local ecological knowledge about cockles may contribute to fisher success (García-Quijano 2009) and temporal stability of the fishery (Begossi 2006), but whether such practices represent *intentional* or *incidental* conservation is beyond the scope of this study (see Pollnac and Johnson 2005; Ruttan 1998). On the other hand, many cockle collectors do seem to have some sort of conservation ethic. For example, experienced cockle collectors say that it is not necessary to plow through the mud “with two hands” or use a machete to scrape or cut the mangrove roots in order to find shells. A good cockle collector will leave the mud relatively undisturbed, neatly inserting his/her hands through the small holes that suggest there is life below the mud. While many informants have suggested this knowledge does not take a long time to develop, others expressed concern that encroaching outsiders are responsible for destructive harvesting practices, particularly in small communities like Isla Costa Rica and Las Manchas. Such suspicions about outsiders have also been noted in the communities around San Lorenzo on the Colombian border (Ocampo-Thomason 2006).

Just as a cockle fisher becomes *enseñado* to certain areas and fishing companions, he/ she also becomes habituated to ecological conditions that differentiate cockle beds. For example, the consistency of the mud or the density of the mangrove branches and roots affect the relative ease and ability for some collectors to gather shells successfully. Some people prefer the harder soils despite the dangers of cutting and scraping their hands on mangrove roots and decaying branches buried in the mud. Others prefer softer soils characteristic of younger mangrove colonies and abandoned shrimp farms, despite the danger of sinking up to one’s waist and losing a boot. One cockle fisher from Isla Costa Rica prefers to work in the *préstamos,* which refer to shrimp ponds walls. He believes that the effluents from the shrimp ponds nourish the filter-feeding cockles allowing his shells to grow quite large, even if his catch contains fewer shells than what others gather from Zone 3. He explains that he is “*enseñado* to harvesting larger shells.” Working predominantly in Zone 2 has enabled him to establish affable relations with the shrimp farmers who grant him special permission to harvest cockles from the mangrove stands that enclose the ponds.

Finally, certain buyers of mangrove cockles also become *enseñado* to purchasing catches of a particular quality. Even though shells sell by the number and not by the size or weight, some buyers prefer to purchase catches considered “good quality,” referring to the average size of shells and proportion of *A. tuberculosa* in the catch. Moreover, the

negotiation largely depends on the relationship between cockle collectors and their buyers. Some cockle fishers sell their catch to the same buyer every time (usually a friend or relative). Others reported in the interviews that they negotiate with multiple buyers before making their sale, although my observations suggest that this practice is less common. In sum, larger catches do not always signify more profitable economic returns for all fishers (Van Holt 2012). Furthermore, economics is not the main driver of resource space preferences or fishing behavior.

Adaptive Challenges and Resilience in Mangrove-Associated Fisheries

Like many small-scale fisheries, several challenges confront the sustainability of Ecuador's mangrove-associated fisheries. Many cockle collectors have expressed concerns about increasing competition, encroachment by outsiders (highlanders, foreigners, or other communities), enclosure by shrimp farming or *custodias*, and pollution (urban contamination or shrimp farm discharge). Some fishers claim they have been displaced by these processes. As each fisher has a set of his/her own preferred gathering grounds, he/she is able to calculate a timely resting period to ensure the sustainable exploitation of particular spots. However, many fishers are worried that no one leaves the sites to rest as long as they should anymore. Furthermore, the timely rotation among gathering grounds is more challenging to coordinate in large communities like Muisne and Hualtaco where competition in a free-for-all is higher. Climate change may pose further challenges to fishery stability as the wet, rainy seasons associated with cockle spawning grow shorter.

Shrimp farms have displaced many fishers from their preferred spots since the 1980s and continue to contribute to other annoyances that make cockle collecting more difficult and dangerous. In addition to occasional confrontations between shrimp farmers and fishers, many people in Muisne complain about "*pica pica,"* a skin irritation associated with a particular kind of algae found around shrimp ponds. Other fishers in Muisne believe that the venomous fish they call "*peje sapo"* is more abundant in the mud around shrimp farms. Environmentally, shrimp farms have disrupted the hydrology of the estuaries, making some areas impassable by motorboat and changing the consistency of the mud in gathering grounds. Shrimp aquaculture is also associated with occasional fish kills and other pollutants that may affect biological processes of settlement and growth of cockle larvae.

In the future, many cockle collectors may leave the fishery to pursue other livelihood strategies. Livelihood switching and "occupational pluralism" is common in many fisheries around the world, despite the immense sense of pride and job satisfaction that many fishers have (McCay 1978; Griffith and Valdés Pizzini 2002; McGoodwin 1990). A reduced fishing effort has many implications for fishery sustainability. For example, other research has shown a positive relationship between migration and catch rates (Hamilton *et al.* 2004).

On the other hand, an unwillingness or inability to leave the fishery (Teh *et al.* 2012) or a strong sense of pride or identity as a fisher might restrict people's ability to be resilient and adaptive in the face of broader social and environmental change (Coulthard 2008). This does not necessarily suggest fishery stability is threatened. Ecuador's recent policy changes in favor of mangrove conservation, its history of activism, and international attention to social justice by organizations like Greenpeace may all

contribute to increased mangrove restoration in the years to come. Newly constructed ancestral identities and a new "sense of peoplehood" offer a promise of empowerment for mangrove users whose life has been previously undervalued (Latorre 2012, 2014). These processes may have deepened the sense of pride among many cockle fishers as "ancestral users of mangroves." Because of this, many cockle collectors hope to protect mangroves and fishery-based livelihoods so they may pass the traditions down to their children. A longitudinal research design is needed to assess how such livelihood decisions affect fishery resilience and how environmental changes, in turn, affect the spatial allocation of fishing effort. Such future research would contribute considerably to understanding about fisheries as complex adaptive systems (Mahon *et al*. 2008; Wilson *et al*. 2013a; Wilson *et al*. 2013b; Daw *et al.* 2012).

Conclusions

The purpose of this paper was to explain patterns in fishing effort allocation as a response to cultural and environmental factors that influence resource space preferences. This research addresses a methodological gap in the literature on folk management identified by Pollnac and Johnson (2005) and contributes to understanding about the social production of fishing space. While small-scale fisheries are highly dynamic and often characterized by livelihood switching, the targeting of multiple species, and uncertainty about fisher decisions, the focus here on Ecuador's cockle fishery has controlled for some of the complexity, allowing for a more nuanced, in-depth analysis of the cultural factors influencing fishing effort allocation in the context of environmental change. This study builds on existing research on benthic fisheries (Basurto *et al*. 2013) and further contributes to qualitative understanding of fisheries as complex adaptive systems in which self-organization emerges out of individual decisions, adaptations, and learning (Wilson *et al*. 2013a; Wilson *et al*.2013b; Berkes *et al.* 2000).

The use of GIS as a data management and analytical tool has many potential management applications (Aswani and Lauer 2006; St. Martin 2004). First, mapping customary use of fishing grounds could aid Ecuadorian communities that continue to witness the illegal encroachment of shrimp farms. Second, the approach used here may provide methodological guidelines for addressing issues raised by McClain and others (2013) concerning representation since the local community coordinated the data collection over a period of several months from a representative sample. This research should further be of interest to Ecuadorian regulatory agencies and research institutes like the INP as they face institutional constraints and other challenges to understanding the complexity of artisanal fisheries, which support thousands of livelihoods in coastal Ecuador. Furthermore, the data gathered through this partnership with Asociación Isla Costa Rica represents a successful case of collaborative learning between researchers and resource users (St. Martin *et al*. 2007) and may serve as a model for research institutions with limited resources. It is hoped that the lessons learned from this research may be applicable to other small-scale fisheries throughout the developing world with limited institutional capacity for research.

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