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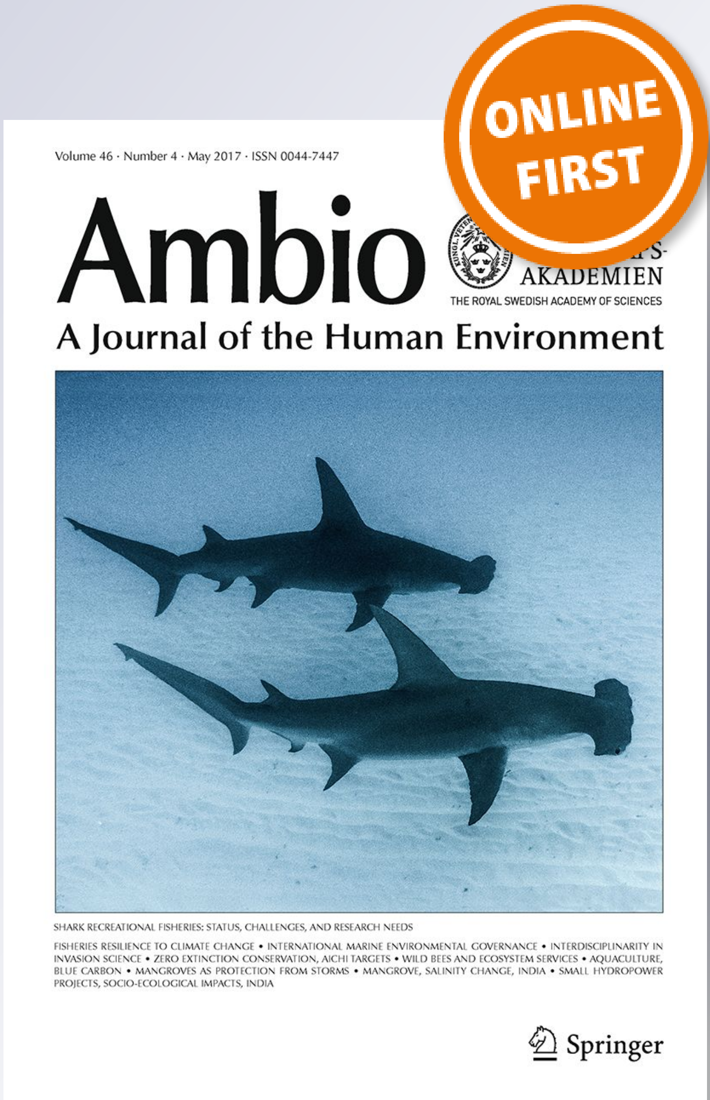

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REPORT

Marine protected areas in Costa Rica: How do artisanal fishers respond?

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Abstract Costa Rica is considering expanding their marine protected areas (MPAs) to conserve marine resources. Due to the importance of households' responses to an MPA in defining the MPA's ecological and economic outcomes, this paper uses an economic decision framework to interpret data from near-MPA household surveys to inform this policy discussion. The model and data suggest that the impact of expanding MPAs relies on levels of enforcement and on-shore wages. If larger near-shore MPAs can produce high wages through increased tourism, MPA expansions could provide ecological benefits with low burdens to communities. Due to distance costs and gear investments, however, MPAs farther off-shore may place high burdens on off-shore fishers.

Keywords Enforcement · Marine reserves · No-take zones · Perceptions · Tourism

INTRODUCTION

The overexploitation of fish stocks in small-scale fisheries negatively affects the ecological processes of marine ecosystems and threatens the livelihoods of people in coastal communities (Berkes et al. 2006). In response, countries implement spatial zoning policies that divide the ocean into exploitation areas and no-take marine reserves or marine protected areas (MPAs). MPAs create positive ecological (e.g., biomass and species richness) and social (e.g., recreation and existence values) benefits within reserves (Lester et al. 2009; Fox et al. 2012) and positive spillover effects on ecological and fishing outcomes outside of the reserve (Halpern et al. 2010; Russ and Alcala 2011). However, questions remain as to whether those spillovers are large enough to offset fishing losses incurred due to restrictions on fishing within the reserve (Sanchirico and Wilen 2001).

As in terrestrial protected areas, the impact of MPA policy on both conservation and socioeconomic conditions relies on how the behavior of the resource's users changes in response to the implementation of the protected area (Robinson et al. 2011, 2014; Albers et al. 2017). Nevertheless, fishery management often fails to address responses to MPAs based on complex livelihood strategies and socioeconomic conditions that characterize artisanal fishers (Thorpe et al. 2011). Further, most of the modeling of fishing area prohibitions assume full compliance with regulations while, especially in a low-income country context of low budgets and costly enforcement, harvest often continues within a defined no-take zone (Sethi and Hilborn 2008). Determining the ecological and socioeconomic impact of an MPA in these settings requires understanding how fishers respond to the location, size, and enforcement of an MPA, including their labor allocation and compliance decisions (Becker 1968; Kuperan and Sutinen 1998; Hauck 2008; Fox et al. 2012; Madrigal et al. 2013).

Compliance with MPAs rules can increase voluntarily if context provides incentives for fishers to adhere to such regulations. Despite the potential for fishers to bear cost burdens from MPAs due to reduced fishing access or fines, fishers may support the establishment of marine regulations if they perceive social, economic, or ecological benefits from the MPA (Kincaid and Rose 2014). Fox et al. (2012) argue that, although fishers face significant upfront costs with MPA establishment from lost access to fishing grounds, livelihoods may shift and diversify to accommodate non-fishing labor opportunities, such as tourism activities. However, the feasibility of a trade-off between fishing and tourism sectors has been contested in the

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literature (Pollnac et al. 2001; Carter and Garaway 2014). Decisions about siting or expanding MPAs should reflect the opportunities for fishers to address MPA-induced income shortfalls with other income-generating activities.

In Costa Rica, nearly 80% of all fish landings come from the small-scale fleet of artisanal fishers for whom that harvest constitutes a central component of livelihoods that often fall below the poverty line (FAO 2011). These fishers are threatened by overexploitation of the resource base and by competition from more sophisticated fishing activities (e.g., semi-industrial and industrial fleets). The Costa Rican government responded by banning particular gear and establishing MPAs along both of its coasts, protecting 17% of the nation's territorial near-shore and internal waters. In addition, as a response to the Convention of Biological Diversity, the government plans to create 11 new MPAs by 2020 (SINAC 2012). Although the government policy emphasizes reduced marine exploitation, the expanded MPAs could generate new "off-sea" labor opportunities and spillover effects to non-MPA fish stocks that could influence both the behavioral response of fishers to MPAs and the MPAs' ecological and socioeconomic impact.

This paper seeks to understand the potential response of Costa Rica's artisanal fishers to expanded MPAs by linking a framework of fisher decisions to descriptive survey data about existing MPAs. Specifically, we develop a simple economic model of fisher labor allocation in response to MPAs. We use this framework as a lens to interpret survey data collected from the Costa Rican Caribbean coast that depicts fisher decisions and perceptions of current fishing regulations. The discussion informs choices about appropriate locations for future establishment of MPAs, particularly in the context of low- and middle-income countries.

MATERIALS AND METHODS

Study site

This study focuses on the northern portion of Costa Rica's Caribbean coast. This region contains Tortuguero National Park (TNP)'s 31 187 hectares (ha) of terrestrial area and 52 681 ha of marine area (MINAET-ACTo 2004; Mora et al. 2006) (Fig. 1). TNP imposes an absolute prohibition (no-take zone) on fishing in all areas of the park but permits guided tours after payment of an entrance fee. The northern part of TNP connects with Barra del Colorado National Wildlife Refuge (CWR), which contains 50 km of coastline and 78 977 ha of canals, lagoons, wetlands, rivers, and river islands that provide habitat for emblematic species such as manatees and marine turtles (Mora et al. 2006). In contrast to TNP, CWR regulates gear choices for fishing located in rivers and canals and charges no entrance fees for guided tours.

The two main fishing communities in the area are Colorado, next to CWR, and Tortuguero, adjacent to TNP (Fig. 1). The National Social Development Index (MIDEPLAN 2013) ranks these communities in the lowest category of development, with many community members depending on artisanal fishing and subsistence agriculture. Tourism, however, represents a significant economic alternative for locals, particularly in Tortuguero where occupations as tour guides and service staff in hotels and restaurants are common. TNP is one the most visited National Parks in Costa Rica; it hosted 105 503 visitors in 2015, of which 80% were foreign tourists (ICT 2017). These differences in economic activities influence differentials in non-fishing wages between the two communities.

In addition, this coastal setting contains two distinct fishing locations: near-shore and off-shore. The spatial and socioeconomic differences across these sites could lead to different levels of fishing across the marinescape and to different responses to MPAs by fishers in each location. In summary, these ecological and township distinctions lead to four groups of fishers: on-shore and off-shore fishers in both Colorado and Tortuguero.

Model framework

How fishers respond to new or expanded MPAs determines both the ecological and economic impact of the MPA. Fisheries economics models provide a framework for understanding fishers' responses. We use a modified version of the classic Schaefer model to understand the impact on fisher decisions of MPAs, in the steady state (i.e., harvest equals the growth of fish stock), for fishers in both near-shore ($j = n$) and off-shore ($j = o$) locations. Total revenue of fishing in location j, TR_j, from fishing effort, E_j, is a function of the price of fish p_j, the catchability coefficient q_j, the carrying capacity K_j, the intrinsic growth rate g_j, and the fishing effort, which reflects a logistic growth function for fish stock:

$$\mathrm{TR}_j(E_j) = p_j q_j E_j K_j \left(1 - \frac{q_j}{g_j}(E_j)\right). \tag{1}$$

In this setting, fishing effort is mainly labor allocated to fishing, that is, $E_j = N_j l_j$, where N_j is the number of fishers and l_j is the amount of labor time allocated to fishing, per fisher.

Fishers can allocate their total labor, L, to fishing or to work for a non-fishing wage, facing a labor time constraint:

$$L = l_j + l_t + l_w, \tag{2}$$

where l_j, l_t, l_w represent time in fishing labor, labor spent traveling to a fishing location, and non-fishing labor,

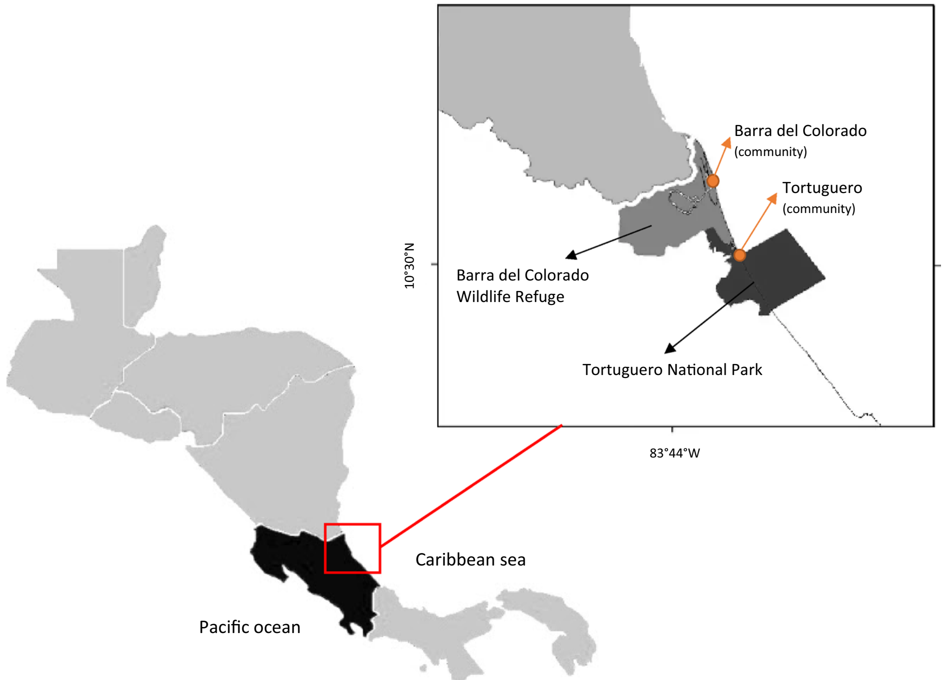


Fig. 1 Location of the fishing communities of Colorado and Tortuguero in Costa Rica

respectively. Fishing in each location entails fixed costs including travel time (distance cost), with the non-fishing wage, w_v, in village, v, as the opportunity cost of time, and gear expenditures per fisher (G_j). Although fishing parameters can differ across fishing locations (j is near or off-shore), including different prices for deep-water fish than near-shore fish, the fisher decisions are based on the wage in the fisher's homeport or village, as subscripted by v. Total costs of fishing become:

$$\mathrm{TC}_j = N_j(w_v(l_j + l_t) + G_j). \quad (3)$$

Setting total revenue (1) equal to total cost (3) for both the near-shore and off-shore locations determines the open access steady state equilibrium, which contains the labor allocation without MPAs in both locations.

Rather than assuming full compliance, and following the economics perspective (Becker 1968), enforcement of MPA restrictions creates disincentives to fishing, with higher rates of enforcement deterring more fishing and providing stronger conservation incentives (e.g., Sutinen and Andersen 1985; Milliman 1986; Byers and Noonburg 2007; Nostbakken 2008; Yamazaki et al. 2014). Thus, the fisher decision to comply with regulations depends on the perceived probability of being caught (m) losing their harvest, and the fine (F) associated with being caught, such that the total revenue that fishers expect from fishing in an MPA becomes

$$E(TR_j) = (1 - m)p_j q_j E_j K_j \left(1 - \frac{q_j}{g_j} E_j\right) - mF. \quad (4)$$

With any positive probability of detection, the expected total revenue of fishing is smaller in the presence of MPAs. As in the forestry literature, the amount of enforcement required to deter extraction declines with distance costs across homogenous resource settings because the marginal incentives to fish decline with increases in those costs (Albers 2010; Robinson et al. 2011). When choosing to fish illegally, the fisher faces a lower total revenue than without enforcement, but the total costs of fishing in that location remain the same across all enforcement levels (as in Eq. 3). The fishing decisions in any location therefore reflect both the total revenue—TR for non-MPA locations and E(TR) for MPA locations—and the total costs of fishing in those locations, with TR = TC in all locations in equilibrium.

The model generates four central observations. First, the level of enforcement of MPA restrictions decreases the expected net benefits of fishing in the MPA, which in turn decreases the amount of labor allocated to fishing in that location. Second, higher fish prices, catchability coefficients, carrying capacity, and intrinsic growth rates lead to higher allocation of labor to fishing in relation to other income-generating activities. Third, higher non-fishing wages reduce the marginal amount of labor allocated to fishing and increase the fixed costs of fishing in distant locations (due to travel time), which may induce non-marginal decreases in fishing at those locations (Albers et al. 2015). Fourth, if different locations impose different gear and travel costs, the labor allocation decisions and the numbers of fishers in those locations will also differ. In summary, this modeling framework suggests that fishers respond to high ecological productivity, high prices, and high catchability by allocating labor to fishing; and respond to high MPA enforcement or compliance incentives, high non-fishing wages, and high-fixed costs by allocating labor away from fishing. However, all ecological parameters equal, fishers choosing to fish in high-fixed cost settings will allocate less time for non-fishing work than fishers in low-fixed cost locations due to their higher marginal value of fishing labor in equilibrium and the labor time costs of traveling leaving less time for wage labor. The modeling framework paired with observations about differences across socioeconomic and ecological settings in Costa Rica provides information about the likely differences in response to MPAs by across near-shore and off-shore fishers and across Colorado and Tortuguero fishers.

Data collection

We collected data using focus groups, in-depth interviews with key stakeholders, and individual surveys with current fishers, following guidelines for good interview practice to gather reliable information in developing countries in a professional and ethical manner (Whittington 2002). Three focus groups and seven in-depth interviews with local community leaders, representatives of the Ministry of Environment, and park rangers produced information about the characteristics of the local fisheries and economies, monitoring efforts, and perceptions on MPA existence and potential expansion. All this information helped us to provide foundations of our economic model and to design a survey instrument for gathering information from fishers. In this regard, we then conducted 95 fisher surveys to generate primary data to validate model predictions' from a representative sample of fishers in Colorado and Tortuguero communities (representing 80% of total fishers in each community). On average, sampled fishers have 20 years of experience and are 40 years old, with slightly higher education levels in Colorado (Table 1). In addition to information about education, family composition, and assets, the individual survey included questions regarding three main topics:

a. *Fishing locations, technology and catches*. One section of the survey included questions on where, what, and how respondents fish, which used printed maps and reference points for each community. The map's zones included rivers and their mouths and two marine zones separated by a sea cliff at five km from the coast, which serves both as a reference point among local fishers and as a point beyond which fish and fishing technologies differ from near-shore. The fishers marked their preferred fishing spots on those maps with the help of trained enumerators. Fishers also classified their main fishing activities as commercial (i.e., selling fish), sport (i.e., sport fishing guides for tourists), and self-consumption.
b. *Perception and responses to regulation*. Another survey section asked questions about fishers' perception of the impact of restrictions on fishing and the enforcement of regulations.
c. *Socioeconomic attributes and labor allocation*. This survey component investigates alternative income-generating activities and labor allocation.

Table 1 General characteristics of the fishers interviewed

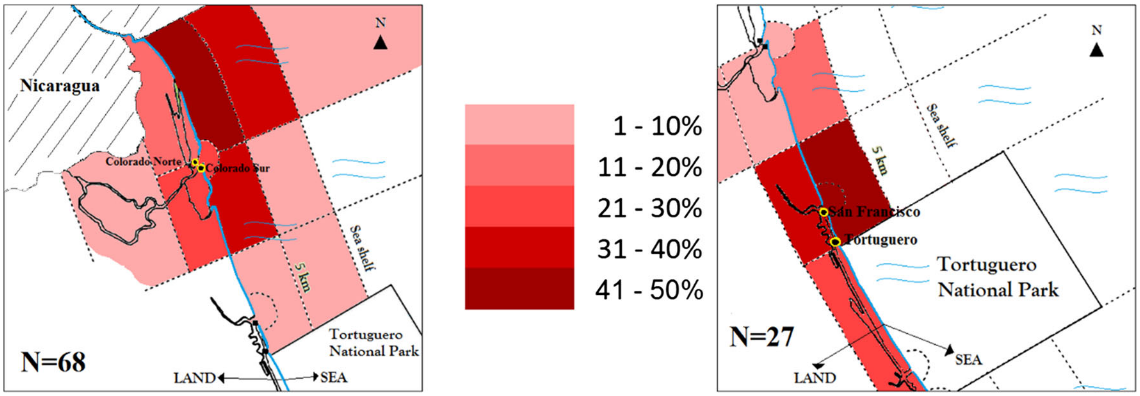
	Colorado	Tortuguero
Total sample (number)	68	27
Age (years, avg)	43	44
Education (% of people with at most…)		
Incomplete primary school	25%	48%
Complete primary school	32%	23%
Fishing experience (years, avg)	22	25

RESULTS

Using the economic decision framework as a lens, this section describes data from the fisher surveys including fishing location decisions, the livelihoods of near-shore and off-shore fishers, the fishing operation, and the perception on MPA regulations.

Fishing locations

Fishers vary in their primary fishing locations and create a pattern of fishing across space (Fig. 2). In the maps, a darker color reflects a larger number of fishers reporting that location as their preferred site for fishing. In line with the biophysical characteristics of the fishing grounds, we define near-shore fishers in this setting as those whose main fishing site is in freshwater (rivers and canals) and within five km of the coast. Off-shore fishers fish beyond that five-km mark. With these spatial definitions, all fishers in Tortuguero are classified as near-shore fishers. In contrast, only 60% of Colorado fishers prefer fishing near homeports and within the five-km mark. Of the potential for four types of fishers, only three exist: Colorado near-shore fishers, Colorado off-shore fishers, and Tortuguero near-shore fishers. Based on the model, these data imply that the lack of off-shore fishing from Tortuguero villagers stems, in



Fishers from Colorado Fishers from Tortuguero

Fig. 2 Spatial distribution of fishing labor (survey results based on map)

Table 2 Economic activities (percentage of respondents)

	Tortuguero			Colorado		
	Near-shore	Off-shore	Pooled	Near-shore	Off-shore	Pooled
Main economic activity (%)						
Fishing	12	–	12	43	86	54
Tourism	72	–	72	24	14	18
Commercial fishing (%)	89	–	89	98	100	99
Farm ownership (%)	36	–	36	36	13	30

Table 3 Characteristics of fishing operations and locations (per boat)

	Tortuguero			Colorado		
	Near-shore	Off-shore	Pooled	Near-shore	Off-shore	Pooled
Operation (avg)						
Fuel (l)	18.9	–	18.9	29.7	61.4	38.7
Time per trip (h)	5.2	–	5.2	8.7	10.6	9.1
Fishers per boat	2.5	–	2.5	2.4	4.1	2.9
Catches in kg	49.8	–	49.8	128.6	203.3	149.4
Price per kg (US$)	6	–	6	4	8	5
Monthly profits reported (US$)	200	–	200	560	1600	900
Gear (%)						
Hand fishing	33.3%	–	33.3%	28.6%		21%
Fishing lines with one hook	55.6%	–	55.6%	44.9%	10.6%	35%
Fishing nets				24.5%	89.4%	42.7%
Boat characteristics (avg)						
Size in meters	14.3	–	14.3	25.6	50.3	38.6
Age in years	10.2	–	10.2	8.8	9.8	9.1
Power in HP	62.5	–	62.5	70.5	141	93.2

part, from access to high enough non-fishing wages to offset off-shore fishing's higher prices (Table 3).

Labor allocations

Different labor allocation decisions lead to different sets of income-generating activities that characterize the livelihoods of fishermen in Colorado and Tortuguero, despite their geographic proximity (Table 2). Within Colorado, 86% of off-shore fishers and 43% of near-shore fishers report fishing as their main economic activity. With all fishers in Tortuguero being near-shore fishers, only 12% rely on fishing for their main income source. Instead, 72% of Tortuguero fishers report that tourism-related jobs provide their main source of income, including jobs as wildlife guides or service staff. With few differences between these coastal areas in terms of ecological productivity, these differences between Colorado and Tortuguero in terms of income shares from fishing reflect higher valued non-fishing (wage) activities that induce labor allocations away from fishing in Tortuguero.

In keeping with the model of labor allocation between fishing and wage work, both Colorado and Tortuguero's near-shore fishers have more diversified livelihoods than off-shore fishers. Regardless of whether fishing or alternative work provides the majority of income, near-shore fishers complement fishing with employment in tourism, agriculture, and construction. Further, 36% of near-shore fishers in Colorado and Tortuguero own land for cattle and agriculture, which provides alternative sources of income. In contrast, off-shore fishers maximize income by focusing on allocating labor time to traveling to the distant fishing grounds and to fishing labor, with high marginal values of fishing labor there once the fixed costs are covered due, in part, to higher prices for fish from the deep off-shore setting (Table 3).

Fishing operation

Fishers reported information on boat characteristics, fishing gear, variable costs (fuel, labor), and catches (Table 3). Near-shore Colorado fishers reported catches two to three times larger than those in Tortuguero due to differences in fishing technology, the amount of fishing labor time, and, based on the model, the number of fishers (N_j) in the two locations. Fishers in Colorado, particularly off-shore fishers, have larger crews, and newer, larger, and more powerful boats, on average, than Tortuguero fishers, which could imply larger catchability coefficients (q) for fishers in Colorado and higher levels of fishing effort. In addition, most fishers in Colorado use fishing nets, while Tortuguero fishers use hand fishing and fishing lines with one hook. Off-shore Colorado fishers spend twice as much fuel and about two extra hours per trip (including travel and fishing time) than Colorado near-shore fishers (Table 3), with larger differences compared to fishers in Tortuguero. Colorado off-shore fishers report catches almost twice those of near-shore fishers and prices approximately one and a half times larger. This price differential is mostly because fish harvested in the deep water are different species, or species at different stages of growth (large adults), compared to that caught at near-shore.

Finally, monthly average revenue reported by off-shore Colorado fishers are approximately US$1600 per boat, compared to US$560 and US$200 per boat reported by their near-shore counterparts in Colorado and Tortuguero, respectively. Although Colorado's off-shore fishers have high fuel consumption and labor time per trip, their high catch levels and prices justify their relatively large fishing operations.

Perception on enforcement

For enforcement activities to change behavior, fishers must have expectations about the probability of being caught and the size of the punishments. In the case of the prohibition on fishing in river mouths, fishers in both communities perceived that approximately 5 out of 10 boats fish illegally in these areas (Table 4). Further, fishers in Colorado approximate that three out of 10 fishing boats are caught by officials in these areas. Similarly, in Tortuguero, fishermen believe that two boats out of 10 are caught when fishing in river mouths. In response to the prohibition on fishing in the marine areas of TNP, fishers in Colorado believe that one out of 10 boats regularly fish within the TNP, while fishers in Tortuguero perceived that three out of 10 boats fish in these areas. Both communities view illegal marine fishing as less prevalent than fishing in river mouths and canals, with two out of 10 illegal fishers caught by officials. Despite these low levels of perceived detection, fishers suggest that restrictions have a positive impact on the ecology of the MPA, with 86% of Tortuguero fishers perceiving that fishing in the MPA is significantly more productive—"much better" on a Likert scale—than in other nearby areas.

Despite the perception of low levels of regulatory enforcement within TNP, the surveys suggest that compliance with regulations might also stem from the perception of the positive benefits derived from the MPA. In Colorado and Tortuguero, respectively, 33% and 57% fishers stated that they incur extra expenses or time when fishing by complying with MPA regulations. The difference between the communities may arise from the proximity of Tortuguero community to TNP. Despite this burden, 57% and 67% of fishers in Tortuguero and Colorado, respectively, perceive the protection of river mouths positively. Similarly, 50% and 31% of fishers in Tortuguero and Colorado, respectively, state that the establishment of the no-take zone within TNP has had a positive impact on their well-being, particularly due to the creation of opportunities associated to tourism activities. Support for future bans in current fishing areas varies from 30% of the near-shore fishers in Tortuguero to 51% and 42% of near-shore and off-shore fishers in Colorado, respectively.

Table 4 Fishers' compliance and enforcement perceptions

	Tortuguero			Colorado		
	Near-shore	Off-shore	Overall	Near-shore	Off-shore	Overall
Fishers fishing in a banned area (out of 10)						
Tortuguero National Park	3.2	–	3.2	1.7	0.4	1.2
Mouth of the river	5.5	–	5.5	4.9	3.0	4.3
Caught fishers (out of 10 fishing in a banned area)						
Tortuguero National Park	2.8	–	2.8	2.2	2.1	2.2
Mouth of the river	1.9	–	1.9	3.0	3.4	3.1

DISCUSSION

This section discusses fisher responses to MPAs using the data and economic decision model as grounding.

Labor allocation decisions and enforcement

The economics literature and the model suggest that MPA policy interacts with the socioeconomic setting to affect people's decisions on labor allocated to fishing, the location of fishing, illegal fishing, and exiting fishing, which together determine the ecological and socioeconomic outcome of the MPA (Albers et al. 2015). In addition to fish stocks, the model and survey data suggest that the most important considerations in household decisions responding to an MPA are off-sea income opportunities, distance and gear fixed costs, and the amount of enforcement and punishment.

The model predicts that fishers with access to high-valued non-fishing labor activities will allocate less labor to fishing than fishers with low-valued non-fishing opportunities. Tortuguero's tourism industry provides relatively high wage jobs to local households, while Colorado's off-sea income opportunities provide lower wages. Our survey data indicate that fishers in Colorado generally fish more than their counterparts in Tortuguero. Similarly, the model predicts that near-shore fishers allocate more time to non-fishing labor activities than off-shore fishers do, as observed in Colorado. That theoretical difference in labor allocation derives from the time costs incurred by off-shore fishers to arrive at off-shore locations, leaving less time to fish or work for wages, and from the higher marginal benefits from labor spent in off-shore fishing than in near-shore fishing due to the costly entry—from expensive deep-water fishing gear—into that fishery. Corresponding to the framework predictions, our data depict off-shore fishers as dedicating most of their labor time to fishing, while near-shore fishers allocate more time to other activities.

Because the opportunity cost of fishing is the non-fishing wage, the relative value of fishing to non-fishing labor determines labor allocations. These interactions imply that higher non-fishing wages draw fishers away from off-shore fishing, in addition to reducing the labor allocation to fishing overall. Reflecting the interaction of wage and location decisions, results on spatial distribution of labor (Fig. 2) indicate that fishers from the higher wage community of Tortuguero do not locate off-shore, while many fishers in Colorado do.

Perception of enforcement rates and penalties also influences fishers' labor allocation decisions because enforcement reduces the expected returns of illegal fishing. As in terrestrial protected areas, MPA enforcement interacts with distance costs to determine behavior, with low levels of enforcement necessary to deter extraction at large distances and high rates necessary to deter nearby extractors (Albers 2010). In keeping with these framework predictions, fishers from Tortuguero, which borders the MPA, report higher rates of illegal fishing in TNP than fishers from the more MPA-distant community of Colorado report, despite both communities describing relatively low levels of enforcement in local MPAs. In both communities, fishers report higher levels of enforcement in river mouths than in the marine areas, though higher levels of illegal harvesting prevail in those locations. Again, fishing in river mouths requires minimal distance costs, which encourages high levels of labor allocated to fishing in those locations that require high levels of enforcement to deter.

Although a low perception of enforcement of regulations in TNP exists, the positive perception of the effect of such regulations on ecological outcomes and on the local tourism industry suggest that other incentives, apart from sanctions, could change fishers' acceptance of MPAs. A rich body of literature suggests that factors other than the lower expected value of fishing due to enforcement can influence compliance (Kuperan and Sutinen 1998; Hauck 2008). In particular, studies report that fishers may support and follow MPAs rules if they perceive social, economic, or ecological benefits (Kincaid and Rose 2014). The opportunities generated by the tourism industry around TNP could be powerful drivers toward compliance. Still, such benefits may not be generated in every context (Pollnac et al. 2001; Carter and Garaway 2014).

MPAs and the local wage

If MPAs generate high wages in nearby areas, the framework suggests that three aspects of the relationship between MPAs and wages contribute to the ecological and socioeconomic impact of the MPA; higher wages reduce fishing, shift from off-shore to near-shore fishing, and diversify income sources.

First, if an MPA becomes a tourist attraction, as TNP has, the employment opportunities in the tourism sector may offset losses associated with restrictions on fishing activities. Higher non-fishing wages can also reduce labor allocated to fishing or cause households to exit the fishery altogether, both of which generate conservation benefits even without enforcement. If higher wages and job opportunities draw qualified people to the area, however, local households may not enjoy the benefits associated with the economic growth of the area and, therefore, not alter their fishing activities. However, in Tortuguero, our surveys indicate that many of the tourism jobs have accrued to local people, leading to reductions in fishing, with likely conservation benefits.

Although the framework predicts that high tourism wages will reduce fishing, several caveats remain. One, not all fishers necessarily want to work in the tourism sector due to enjoyment of their fishing occupation (Pollnac et al. 2001) or because tourism is considered a risky activity, associated with shocks and vulnerabilities (Carter and Garaway 2014). Therefore, a permanent displacement of fishers as a result of tourism cannot be guaranteed despite increased non-fishing wages (Pollnac et al. 2001). Two, the benefits of tourism might not accrue to all fishers, with the poorest households often excluded due to lack of social connections or language skills (Carter and Garaway 2014). Three, tourism-related wage activities are seasonal and may not provide sufficient alternative livelihood activities year-round (Carter and Garaway 2014). Four, tourism-related wage activities might be insufficient to absorb the potential shift of labor effort from fishing to tourism. Although households report positive outcomes about the MPA regulations due to the associated tourism gains, expanding the MPA or creating new MPAs may not generate similar alternative income activities. To our knowledge, no studies of the demand for MPA tourism exist for the Caribbean coast of Costa Rica to identify the response of tourists to increasing MPAs. Similarly, no studies describe the relationship between tourist numbers and job creation or wages in this area. Such studies would be needed to determine whether the MPA-wage relationship observed in Tortuguero, which leads to reductions in fishing and to related conservation benefits, would hold with expanded or new MPAs.

Second, another likely response to higher wages associated with MPAs involves reducing off-shore fishing while increasing near-shore fishing. That change occurs due to the time costs of accessing off-shore areas reflecting the opportunity cost of time, here wage, and the advantages of being able to allocate time to both fishing and non-fishing labor opportunities. That location change, however, could lead to both cultural and ecological conflicts in the near-shore areas. In particular, river mouths already suffer high levels of illegal fishing, with MPA managers and households alike expressing frustration. If MPAs increase non-fishing wages, and those wages induce fishers to locate near-shore, conflict between guards and fishers, and among fishers, could grow. In addition, MPA managers describe the highly bio-diverse canal and river mouth ecosystems as fragile, and the tourism-drawing sea turtles require protection from some types of fishing gear, especially near-shore and on beaches. Higher non-fishing wages that induce off-shore fishers to relocate to near-shore areas can then threaten the ecological system, especially with limited enforcement.

Third, MPA-induced high wages influence households to reduce fishing and increase wage labor, which effectively diversifies their income. Near-shore fishers in our sample typically undertake both fishing and other income-generating activities. Off-shore fishers, however, typically have made significant gear investments and generate less of their income from alternative activities. Those characteristics make their income less diversified than that of near-shore fishers. Expanding enforced MPAs into near-shore areas would push near-shore fishers toward allocating more labor to on-shore activities. Expanding enforced MPAs into off-shore areas, however, could pose substantial burdens on off-shore fishers due to their relative lack of experience with non-fishing opportunities and large investments. Because fishers make decisions about the location and amount of fishing they undertake, the location and size of MPAs interacts with the non-fishing wage to determine the ecological and socioeconomic impact of the MPA.

Expanding the MPA network on the Costa Rica's Caribbean Coast

In addition to considering the enforcement requirements and the potential for tourism-based wage growth, conservation policy should consider socioeconomic heterogeneities influencing the response of individuals to new regulation.

First, Colorado and Tortuguero's proximity may belie their differences. Labor allocation choices explain the difference between the sources of household income in Colorado and Tortuguero: Colorado relies on fishing and Tortuguero relies on tourism. Given these differences in labor and income sources, and using the economic decision framework, identical MPA regulations in these two locations would have different effects. Fishers in Colorado and Tortuguero would respond differently to identical MPAs due to differences in profitability of non-fishing labor opportunities. That difference could induce higher levels of illegal fishing and more reallocation of fishing labor to other fishing grounds in Colorado than Tortuguero, affecting the ecological outcomes and the economic burden of the MPA. Thus, a blanket MPA policy can have a different impact and effectiveness, even when placed in two adjacent small communities.

Second, answers to the survey's question about support for future regulation reveal the complexities of extending these policies. For example, despite fishers from Tortuguero reporting a positive effect of the ban on fishing in the park for their communities, only 29% of Tortuguero fishers would support new fishing-ban areas. These respondents may fear that further no-take zones would limit fishing without providing compensatory gains in alternative income-generating activities. On the contrary, 49% of fishers in Colorado would support new fishing-ban areas. Comparing across community responses and examining the modeling framework raise the hypothesis that the baseline of actual regulation plays a major role in determining the support for new regulation. Fishers likely face different tradeoffs between marginal costs and marginal benefits of MPA expansion based on their current MPA restrictions. Tortuguero fisher responses suggest a point beyond which more regulation would impose higher marginal costs than benefits, thus limiting support for further MPA expansion.

CONCLUSION

Because MPAs must change fishing behavior to produce conservation benefits, understanding the socioeconomic setting and fishers' perceptions in developing MPA plans can lead to superior ecological and socioeconomic outcomes. The model and data suggest that the impact of expanding MPAs relies on levels of enforcement and non-fishing labor activities.

If larger near-shore MPAs can produce high wages through increased tourism, MPA expansions could provide ecological benefits with low burdens to communities. Whether expanding MPAs near these communities will impose significant costs on fishers depends on fishers' ability to find other productive uses for labor. MPAs that lead to tourism that increases or improves non-fishing labor opportunities could provide ecological benefits with low burdens to communities. In Tortuguero, the national park has generated enough tourism to offset the losses associated with reduced access to fishing grounds for most fishers interviewed. Expanding the MPA toward Colorado might generate similar tourism opportunities for that community, but no studies exist on the impact of MPA expansion on non-fishing labor opportunities, including tourism potential. Given the relative reliance of Colorado fishers on fishing, further analysis of the MPA's ability to generate alternative income sources is necessary to understand the potential ecological and economic impact of expanded MPAs.

Due to distance costs and gear investments, however, MPAs farther off-shore may place high burdens on Colorado's off-shore fishers. For example, expanding the park along the coast and enforcing park regulations on river and near-shore fishing grounds would alter the amount of fishing for fairly well-diversified near-shore fishers. Similarly, expanding the MPA with enforcement beyond 5 km would dramatically alter the livelihoods of the off-shore fishers who specialize in fishing in that location. In addition, MPA policies that limit off-shore fishing or that increase non-fishing wage could induce more fishing near-shore, which may imply ecological costs in the biodiverse and fragile near-shore ecosystems.

Overall, despite proximity and ecological similarities between coastal communities in northeastern Costa Rica, heterogeneity across and within the groups of fishers will lead to diverse responses to expanding MPAs. The specifics of the expansions and responses will determine the MPA's impact on ecological and socioeconomic outcomes.

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