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Poverty and the use of destructive fishing gear near east African marine protected areas

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SUMMARY

Poverty may be an important influence on the exploitation of marine resources in tropical developing countries. A number of studies have hypothesized that destructive fishing gears, which can degrade habitat, capture high proportions of juvenile fish and ultimately lead to reduced yields, are primarily used by the poorer segments of society. However, few studies have empirically tested this relationship. This paper examines relationships between the use of destructive seine nets and thirteen socioeconomic conditions in communities adjacent to three peri-urban marine protected areas in east Africa. Fishers using destructive gears were younger, less likely to have capital invested in the fishery, had lower fortnightly expenditures and were poorer in two multivariate indices of material style of life. Based on the two multivariate material style of life indices, a binary logistic regression model classified whether fishers used destructive gears with almost 70% accuracy. These findings are broadly consistent with the literature on poverty traps, which are situations in which the poor are unable to mobilize the resources required to overcome low-income situations and consequently engage in behaviour that may reinforce their own poverty. Managers aiming to reduce destructive gear use may need to partner with civil society and donors to help break poverty traps.

Keywords: artisanal fishery, beach seine, destructive fishing gears, human-environment, marine protected area, social-ecological system, socioeconomic

INTRODUCTION

Coral reefs provide critical fishery resources to millions of people, primarily in developing countries (Donner & Portere 2007). Yet overfishing is severely eroding key ecological goods and services that coral reefs provide (Jackson *et al*. 2001; Newton *et al*. 2007). Balancing human needs for protein with the long-term sustainability of reef ecosystems has become a critical challenge.

Some of the key tools fisheries managers have employed to balance these often-competing needs have been establishing marine protected areas (MPAs) and the prohibition or management of specific fishing gears. Properly complied with, MPAs can help to buffer the impacts of overfishing, but, in developing countries, MPAs are often too small to sustain the broader seascape (Graham *et al*. 2008). Thus, other management measures such as gear restrictions are also required outside of protected areas to help sustain reef ecosystems (McClanahan *et al*. 2008*a*; Cinner *et al*. 2009*a*). Certain fishing gears have a higher propensity to physically break corals, capture a high proportion of juvenile fish (Mangi & Roberts 2006; Mangi *et al*. 2007) and target species that have feeding characteristics that help promote the resilience of coral reefs (Cinner *et al*. 2009*b*), and are thus good candidates for bans (McClanahan & Mangi 2004). Destructive gears used on coral reef ecosystems can include seine nets (beach seine and ring nets; McClanahan & Mangi 2001; Jiddawi & Ohman 2002), explosives (Pet-Soede *et al*. 1999) and poison (Jones & Steven 1997).

In East Africa, seine nets are one of the most widely used destructive gears. In Kenya, their use has been illegal since 2001, but is often tolerated (McClanahan *et al*. 2005; Signa *et al*. 2008). Some communities have effectively excluded their use, using traditional institutions or co-management approaches (McClanahan *et al*. 1997; McClanahan 2008*a*; Hicks *et al*. 2009). In Tanzania, beach seine nets are also illegal (Jiddawi & Ohman 2002; N. Jiddawi, personal communication 2009). Beach seine nets are typically manned by 10–25 fishers, who pull the net across a shallow bottom. Beach seine nets can be highly damaging to the substrate and their catch can consist of up to 70% juvenile fishes (Mangi & Roberts 2006). Studies have shown that catch rates per area of reef and per fisher are higher in areas where beach seines are excluded (McClanahan *et al*. 1997; McClanahan & Mangi 2001). Ring nets (also called mini-purse seine nets) are also common in Tanzania. They are manned by a similar size crew, but can be used in deeper waters because they have a 'draw string' which closes the bottom of the net. Although legally they are only supposed to be used in deep water to target sardines (N. Jiddawi, personal communication 2009), they are frequently used on or around coral reefs (J Cinner, personal observation 2006).

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There are frequent attempts to persuade East African fishers who use destructive gears to change their behaviour, either by stopping fishing entirely, or by switching to alternative fishing gears (Signa *et al.* 2008). In some instances, gears are simply prohibited, but low levels of formal enforcement capacity and a lack of alternatives often leads to low levels of compliance with these regulations (Evans 2009). In other cases, gear-exchange programmes or alternative livelihoods are developed (Verheij *et al.* 2004). As with many alternative livelihood programmes, assumptions about the social conditions and motivations of the fishers are frequently made, which can result in spectacularly unsuccessful programmes (Allison & Ellis 2001; Pollnac *et al.* 2001; Sievanen *et al.* 2005; Pollnac & Poggie 2006).

Successfully reducing destructive gear use will depend, at least in part, on a better understanding of these fishers and the socioeconomic drivers behind their practices. A number of studies have suggested that poverty coupled with decreasing yields associated with environmental degradation may create conditions that force fishers to use destructive fishing gear (see for example Pauly 1990;Guard & Masaiganah 1997; Toby & Torell 2006), although few studies have attempted to make this link empirically (Cassels *et al.* 2005; Silva 2006). The concept of poverty is multi-dimensional, and can incorporate aspects of income or expenditures, access to infrastructure, education, the diversity of livelihood portfolios and social capital (Narayan 1997).

To help better understand the socioeconomic context in which destructive seine net fishers in East Africa operate, this paper examines socioeconomic characteristics of beach seine users operating adjacent to three East African MPAs. In particular, this paper tests the hypothesis that fishers using beach seine nets are marginalized. To test this, I (1) examined differences in thirteen socioeconomic characteristics between fishers using destructive gears and those that do not, and (2) used these socioeconomic characteristics to predict whether fishers use seine nets or not.

METHODS

I surveyed 115 fishers in three study areas in Kenya and Tanzania (Table 1). In Kenya, I selected study sites adjacent to the Mombasa and Malindi MPAs. Mombasa study sites included the communities of Bamburi and Utange, as well as Bamburi Beach landing site and Marina landing site. Malindi study sites included the communities of Shela and Mijikenda. In Tanzania, sites included the Kunduchi and Uninio communities adjacent to the Dar Es Salaam MPA. Communities were selected as part of a larger project examining coral reef social-ecological systems in the Western Indian Ocean (McClanahan *et al.* 2008*b*; Cinner *et al.* 2009*a*). In both countries, several other communities were also studied, but to minimize possible confounding effects of urbanization and protection, sites were omitted if (1) they were rural, or (2) there were no MPAs in the vicinity. Previous research has shown that there are significant differences in the socioeconomic characteristics between fishers in rural and urban environments and also near and far from protected areas in Kenya (Cinner *et al.* 2010). Thus, only peri-urban sites adjacent to protected areas were included in this study. The non-random selection of communities limits what inferences can be made on non-study areas.

Table 1 The number of fishers interviewed by site.

Site	*Non-seine net*	*Seine net*	*Total*
Dar Es Salaam	32	10	42
Malindi	16	20	36
Mombasa	18	19	37
Total	66	49	115

Households within a village were systematically sampled, where a sampling fraction of every *i*th household (for example 2nd, 3rd, 4th) was determined by dividing the total village population by the sample size. A household was defined as people living together and sharing meals. The number of fishers surveyed per community ranged from 37–42 (Table 1). Respondents were asked about education, participation in community groups, age, fortnightly expenditures, per cent of fish bartered or sold, migration status, their capital investment in the fishery, gear use, their involvement in other occupations and indicators concerning their material style of life (MSL) (Table 2). The number of jobs per household was log transformed to reduce the effect of outlying values and reflect the greater importance of each additional occupation if households had fewer occupations.

Low densities of fishers were living in the communities associated with the Mombasa MPA, making the probability of encountering fishers during household surveys very low. Thus, it was necessary to supplement these household surveys with surveys of fishers from the landing sites. Landing site chairmen provided lists of all fishers at the site and fishers were randomly selected from the list. I crosschecked these lists with fisheries department information to validate the total number of fishers at each location.

Data analysis

I developed a MSL scale based on the presence or absence of nine household possessions, such as electricity, fan, video player, TV, a toilet, radio and the type of material the house was constructed from (Table 2). The interrelationship between these items can be used to construct a MSL scale (Pollnac *et al.* 2001). The items were factor analysed using the principal component method. I used a scree test to determine the total number of factors to be included and removed items with low factor loadings, which resulted in the removal of one item: a gas or electric stove. I calculated a score for each of the MSL components for each household based on the presence or absence of items in their household. Each item contributes to the component score based on a proportional transformation of its loading (Table 3). Items with high positive loading have a stronger contribution than those with low or negative values.

Table 2 Socioeconomic indicators.

Indicator	*Description*
% Fish sold	% of a 'normal' days catch that is sold or bartered
Age	Age of respondent (in years)
Capital investment in fishery	1 if fisher owns capital intensive gear (nets, traps, or boat), 0 if not
Fortnightly expenditures	Cash expenditures over the past two weeks (recorded in local currency and converted to US$ purchasing power parity)
Gear diversity	Number of different fishing gears used by the fisher
Material style of life (MSL)	Two principal component scores based on the type of wall, floor, roof and the presence or absence of a radio, toilet, electricity, TV, video player and fan (see Table 3 for factor loadings)
Migration	Whether fisher had immigrated into the area (yes or no)
Number of community organizations	Number of community organizations the household was involved with
Number of jobs per household	Total number of jobs performed by household members (log transformed)
Occupational diversity	Number of different occupational types performed by household members (for example fishing, farming, informal economy, salaried employment. If fishing was conducted by two household members, it scored as one occupation)
Occupational mobility	1 if fisher had moved jobs in past five years and preferred the present occupation, 0 if not
Years of formal education	Number of years of formal education the respondent had completed

Table 3 Socioeconomic characteristics of fishers. * = not mean value, na = not applicable.

Indicator	*Non-seine net*			*Seine net*		
	n	*Mean*	*Std deviation*	*n*	*Mean*	*Std deviation*
% of fish sold	59	92.2	9.79	49	93.63	9.44
Age	62	41.06	14.87	51	35.8	12.68
Capital investment in the fishery (%)	62	55*	na	53	34*	na
Fortnightly expenditures	62	170.43	95.14	52	130.52	74.10
Gear diversity	61	1.18	0.43	53	1.36	0.65
MSL amenities factor	62	0.18	1.20	53	−0.21	0.65
MSL poverty factor	62	−0.35	0.86	53	0.41	1.00
Migrants (%)	58	60*	na	49	69*	na
Number of community organizations	62	0.74	0.87	53	0.77	0.11
Number of jobs per household (ln transformed)	62	0.57	0.66	53	0.70	0.67
Occupational diversity	61	1.21	0.45	53	1.11	0.44
Occupational mobility (%)	62	19*	na	53	25*	na
Years of formal education	62	4.77	3.74	53	5.26	3.92

I tested for differences in socioeconomic conditions between fishers using destructive gears and those that did not use destructive gears using independent samples (T-test for ordinal variables, a Mann-Whitney U test for ordinal variables and a chi-squared test for the binary indicators). I used a backward stepwise binary logistic regression model to predict whether or not fishers used beach seine nets based on the independent socioeconomic variables. This was done manually by sequentially removing the least significant variables until only significant ($\alpha = 0.05$) variables remained in the model. For the logistic regression analysis, I examined all independent variables for correlations and collinearity. While several independent variables displayed statistically significant bivariate correlations using the Spearman's rank test, correlation coefficients were low (<0.4), and none of the variables displayed high variance inflation factors (all < 1.6), so no variables were removed from the analysis because of collinearity. Two variables (migration and the percentage of fish bartered or sold) were missing a substantial number of cases (8 and 6, respectively) and consequently I removed these before running the regression analyses.

RESULTS

Principal component analysis of the MSL items resulted in two factors explaining 62.4% of the variance. Items with high positive loadings on factor 1 include dirt walls, thatch roof, dirt floors and no toilet, while a radio had a high negative loading (Table 3). These items are largely associated with poor housing. Owing to the positive loading of items associated with

Table 4 Socioeconomic factors predicting destructive gear use based on a backward stepwise binary logistic regression model. The exponent of B is interpreted as the odds ratio. Thus, for every unit increase in the poverty factor, respondents are more than twice as likely to use destructive gear.

Variable	*B*	*p*	*Exp(B)*
Poverty factor	0.82	0.00	2.28
Amenities factor	−0.52	0.05	0.59
Constant	−0.20	0.34	0.82

a poorer household, a high score on this factor actually equates with a low MSL, thus, I call this a 'poverty factor'. This factor ranged between −1.24 and 1.68, with a mean of 0 and standard deviation of 1. Items with high positive loadings on factor 2 include video players, fans, TV and electricity. I call this an 'amenities factor.' This factor ranged between −0.76 and 3.41, also with a mean of 0 and standard deviation of 1.

There were significant differences in age (t = 2.0, df = 111, $p = 0.05$), fortnightly expenditures (t = 2.5, df = 111, $p = 0.13$), poverty factor (t = −4.3, df = 113, $p < 0.001$), amenities factor (t = 2.2, df = 97, $p = 0.03$) and capital investment in the fishery ($\chi^2 = 5.0$, df = 1, $p = 0.025$) between fishers using destructive gears and those not using these gears (Table 3). The final logistic regression model included just two independent socioeconomic variables: the poverty factor and the amenities factor (Table 4). The model correctly predicted 69% of the cases and had a Nagelkerke R^2 of 0.232. The Hosmer and Lemeshow chi-squared goodness of fit was not significant ($\chi^2 = 3.5$, df = 8, $p = 0.90$) and the Omnibus test of model coefficients was significant ($\chi^2 = 22.0$, df = 2, $p < 0.001$), indicating that the model adequately fits the data. There was a positive association between the poverty factor and destructive net use, a negative association between the amenities factor and destructive net use.

DISCUSSION

Poverty is often believed to be a driving force in the exploitation of marine resources in tropical developing countries, although relationships are complicated and not well understood (Bene 2003; Silva 2006; Cinner *et al.* 2009*a*). Consistent with another empirical study from the region (Silva 2006), I found that fishers who used destructive gears were poorer. In particular, destructive gear users were more likely to have a lower MSL, as indicated by higher poverty factor scores and lower amenity factor scores. The likelihood of fishers using destructive gears could be correctly classified almost 70% of the time based on just these two multivariate indices of well-being. Destructive fishers also had significantly lower fortnightly expenditures, were significantly younger and were less likely to own capital in the fishery, but these variables were not significant in the regression model.

The finding that destructive gear users tend to be poorer is broadly consistent with the concept of a poverty trap (Barrett *et al.* 2006; Enfors & Gordon 2008). Poverty traps are situations in which the poor are unable to mobilize the resources required to overcome low-income situations, and thus they engage in behaviour that may reinforce their own poverty (Dasgupta 1997; Barrett *et al.* 2006; Cinner *et al.* 2009*a*). Other research suggests that poorer fishers are drawn into beach seine crews because of the low capital investment and skills required (Obura 2001; Signa *et al.* 2008), but in the Kenyan artisanal fishery, profitability is lowest for crew members without capital invested (Mangi *et al.* 2007). Use of beach seine nets can severely degrade the condition of the resource, resulting in lower overall fishery yields (McClanahan & Mangi 2001), and ultimately creating a feedback cycle that reinforces both poverty and environmental destruction (Bunce *et al.* 2009). In a related study, Cinner *et al.* (2009*c*) found that poorer fishers in Kenya were also less likely to exit a declining fishery.

Although most studies empirically investigating aspects of poverty and destructive gear use have found a relationship (for example see Cassels *et al.* 2005; Silva 2006), the inconsistencies between the studies suggest that relationships between destructive gear use and specific socioeconomic conditions are complicated and may be dependent on context. For example, in Indonesia, a lower level of education (which was not significant in this study) was related to use of destructive gears, but income levels were not (Cassels *et al.* 2005). Other contextual socioeconomic aspects not covered in this study, such as local histories, tenure arrangements and social organization (such as caste systems) may also play an important role in determining the types of gears used (Cinner & Aswani 2007; Coulthard, 2008; Evans 2009).

Attempts to manage seine net use need to consider the role of fisheries in the wider economy. Pauly (1990) noted that fisheries can be perceived as a 'dump for excess labor'. This can be particularly relevant in places such as coastal Kenya, where there are few formal economic sector jobs (Cinner *et al.* 2009*d*) and there are low costs involved in beach seine fisheries. Seine net fishers are frequently characterized as young day labourers, with few skills and little or no capital invested in the fishery (Mangi *et al.* 2007). Consistent with other studies, I found that seine net users were less likely to have capital invested in the fishery (Obura 2001; Silva 2006) and were also significantly younger, although these variables were not significant predictors of whether fishers used destructive gear in the logistic regression model. It is likely that the seine net fishery at these sites provides an important livelihood income for poor young labourers (Mangi *et al.* 2007; Signa *et al.* 2008). Development programmes, such as alternative income or gear exchange programmes designed to reduce seine net use, will need to better understand the socioeconomic context in which these fishers operate, including fishers' reasons for engaging in the fishery and the non-economic satisfactions gained from fishing (Pollnac *et al.* 2001; Sievanen *et al.* 2005; Pollnac & Poggie 2006).

CONCLUSIONS

Managers aiming to reduce destructive gear use should consider how socioeconomic conditions may be driving involvement with the gear. Reducing destructive gear use may involve breaking poverty traps, which is generally beyond the scope of fisheries management agencies, particularly in tropical developing countries. Partnerships between fisheries departments, donors and civil society may be critical for effective fisheries management. These partnerships should include strengthening the emerging community-based management system (in Kenya, called beach management units), poverty alleviation strategies and the development of gear exchanges and/or micro-financing to allow fishers access to legal fishing gears (Signa *et al.* 2008).

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