Conservation Letters
A journal of the Society for Conservation Biology
Open Access

LETTER

Mosquito Net Use in an Artisanal East African Fishery

Emma R. Bush[1,2], Rebecca E. Short[2,3], E. J. Milner-Gulland[2,4], Kirao Lennox[5], Melita Samoilys[6], & Nicholas Hill[7,8]

[1] Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling, Scotland, FK9 4LA, UK
[2] Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot SL5 7PY, UK
[3] Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK
[4] Department of Zoology, University of Oxford, South Parks Road, Oxford OX1 3PS, UK
[5] A Rocha Kenya, Watamu, 80202, Kenya
[6] CORDIO-East Africa, PO Box 24562, Nairobi 00502, Kenya
[7] Conservation Programmes, Zoological Society of London, Regent's Park, London NW1 4RY, UK
[8] Centre for Ecology and Conservation, University of Exeter, Penryn, Cornwall TR10 9EZ, UK

Keywords
Artisanal fishing; Kenya; livelihoods; malaria; mosquito net; overfishing; selectivity; juvenile fish.

Correspondence
E.J. Milner-Gulland, Department of Zoology, University of Oxford. OX1 3PS, UK.
E-mail: ej.milner-gulland@zoo.ox.ac.uk

Received
20 October 2015
Accepted
12 July 2016

doi: 10.1111/conl.12286

Abstract

Widespread, anecdotal reports of the use of bed nets designed for malaria control ("mosquito nets") in artisanal fisheries have led to concern from health and natural resource management sectors. However, mosquito net fishing (MNF) may play an important role in the livelihoods of artisanal fishers, an aspect not yet investigated. At a coastal Kenyan site among Giriama fishers, nearly half of homesteads interviewed used mosquito nets as fishing gear, targeting juvenile fish and prawns for subsistence and sale. The majority of mosquito net (MN) fishers here were men, suggesting that the assumption that MNF is a female activity is not valid in this case. However, MN use for fishing at this site is unlikely to impact malaria protection as fishers used old or surplus nets. Respondents perceived both positive aspects of MNF (e.g., food and income) and negative aspects (e.g., impact on fishery). As mosquito nets are widely available, they may enable new entrants to access fisheries. There is a critical need to review current management responses, which predominately focus on banning the practice, and instead promote integrated strategies for sustainable livelihoods.

Introduction

One million people are estimated to die of malaria each year, and malarial illness and mortality cost African economies USD 12 billion annually (RBM 2013). The World Health Organization promotes distribution of free or subsidized long-lasting insecticide-treated nets (hereafter mosquito nets) to all at-risk populations (WHO 2012). Anecdotal evidence suggests that these nets are increasingly employed in alternative activities, including as gear in both freshwater and coastal artisanal fisheries. With a large investment in this strategy, there is understandable concern that recipients should use nets as intended (Butunyi & Oloo 2008; Shah 2010), although alternative use of old or surplus nets may have little impact on malaria protection (Eisele *et al.* 2011).

Resource managers are concerned about the ecological effects of using mosquito nets in fisheries relating to two main issues. As freely available and easily deployed gears, they may facilitate the entry of new individuals into fishing, seeking the relative livelihood and food security fishing offers as an occupation of "last resort" (Béné 2003). Additionally, the small mesh size and lack of selectivity of mosquito nets defy conventional management objectives of protecting juveniles (Hilborn & Walters 2013). At a national level, despite limited empirical evidence on the prevalence and ecological effects of mosquito net fishing (MNF), some east African countries have begun to enforce bans based on mesh-size legislation (Fisheries Department, Ministry of Agriculture, Livestock and Fisheries 1991; Ministry of Livestock and Fisheries Development 2003; Pereira *et al.* 2014).

There are numerous anecdotal references to MNF in the media globally in malarial zones (Butunyi & Oloo 2008; Shah 2010; Gettleman 2015), and it is detailed in national reports on fishing practices in coastal East Africa (Jiddawi & Öhman 2002; Gough *et al.* 2009; Samoilys *et al.* 2011). Mosquito nets are generally deployed in shallow water, dragged by two or more fishers to catch pelagic-neritic fish, molluscs and crustaceans (Srivastava *et al.* 2002; Lopes & Gervasio 2003; Samoilys *et al.* 2011; McLean *et al.* 2014). It is commonly perceived that MNF is primarily undertaken by women and children (Jiddawi & Öhman 2002; Van der Elst 2003; Abbott & Campbell 2009; Hamerlynck *et al.* 2011).

There are few publications focused on MNF in the peer-reviewed literature. Manase *et al.* (2002) analyzed catch and effort data for Lake Malawi, describing a marked increase in MN ownership in the late 1990s. Minakawa *et al.* (2008) quantified the use of MNs for catching and drying small fish around Lake Victoria, Kenya, describing motivations for MNF as the availability and low cost of the gear. Darkey & Turatsinze (2014) assessed fisher knowledge of local legislation in Beira, Mozambique, and found ubiquitous use of mosquito nets by fishers in certain communities despite nationwide bans. The most comprehensive study, by McLean *et al.* (2014), in Tanzanian villages bordering Lake Tanganyika found over 87% of households engaged in MNF, with 97% of these receiving nets for free and 65% subjectively linking MNF to decreasing catches.

The policy context for MNF involves three main sectors: health, natural resource management, and local communities. Figure 1 outlines the likely impacts on and concerns for MNF for each group. It is important to note that while all actors influence the nature of MNF, they operate on different policy-relevant scales and motivations toward participating in conservation initiatives for MNF are likely to differ widely.

Current management approaches reflect the premise that allowing juvenile fish to mature before entering the fishery should enhance sustainability by protecting stocks from collapse even when exploitation rates are high (Myers & Mertz 1998). This "spawn-at-least-once" principle has led to bans under mesh size legislation in many countries (Fisheries Department, Ministry of Agriculture, Livestock and Fisheries 1991; Ministry of Livestock and Fisheries Development 2003; Pereira *et al.* 2014). Measures to increase selectivity of fishing toward larger individuals are particularly common in artisanal fisheries, where they are seen as easier to implement than effort controls (McClanahan & Mangi 2004). Recently, an academic debate has examined the basis for selective fishing, and suggested that a more even distribution of fishing effort across size classes may be a useful component of ecosystem-based fisheries management (Garcia *et al.* 2012). This applies particularly in artisanal fisheries (Kolding *et al.* 2015) where concerns over practicalities such as commercial feasibility and carbon costs are of less concern. Consideration should be given to monitoring feasibility and removal of important forage fish for vulnerable species such as birds and marine mammals (Burgess *et al.* 2015). It may be difficult to enforce bans on MNF, because small mesh nets are more likely to be fully owned by the user than other legal gears (Malleret 2004), which are often rented or operated by an informally employed workforce (Lopes & Gervasio 2003; Carter 2012). Wide availability of mosquito nets may enable poorer people to engage in fishing and enhance food security (Jacobsen *et al.* 2013). Thus, there is increasing interest in understanding more about mosquito net fisheries to better inform management.

To date, there is almost no information on either the biological or socioeconomic aspects of MNF to inform this debate. This study aims to be a starting contribution to the literature around MNF to build the body of evidence required for making effective management decisions. To do this, we undertook a detailed case study of villages bordering Mida Creek in the Gede/Watamu administrative zone of the Kenyan Coast Province. The area was chosen due to the confirmed presence of MNF in the region and the participation of a local community conservation organization (A Rocha Kenya) in the study.

The objectives of the study were to:

1. Quantify the prevalence of MNF in a coastal community, and its relationship to bed net use for malaria control.
2. Evaluate the social and demographic make-up of mosquito net fishers compared to the rest of the community.
3. Explore community perceptions of the state of the fishery and relationship to MNF.

The study is the first to explore the socioeconomic role of MNF in a detailed case study, with a view to informing decision making and setting the stage for future studies in other areas.

Methods

Site description

Mida Creek is a marine reserve covering 32 km² bordered by three tidal flats and surrounded by mangroves. The Kenyan Wildlife Service manages the protected area and fishing is permitted in the reserve. The creek is bordered by 11 villages, with an estimated population of >9,000 in 2011, mostly ethnic Giriama (Carter

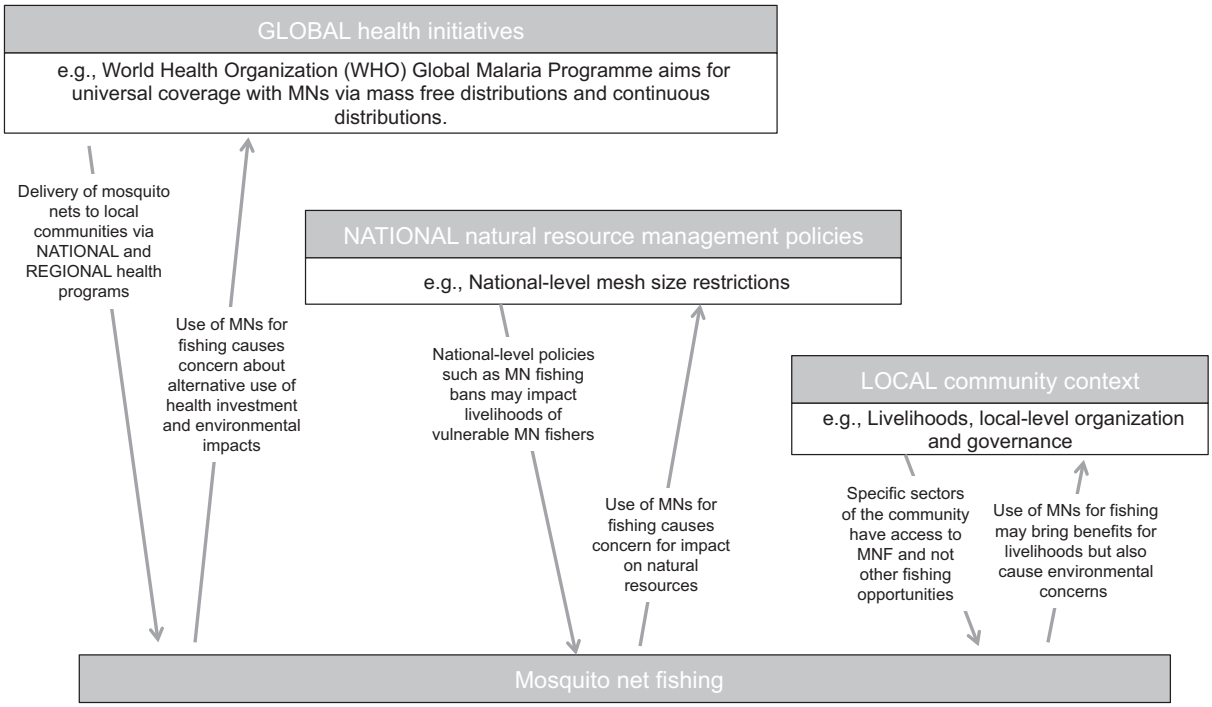

Figure 1 Likely influences and concerns of main actors for mosquito net fishing and the scale of their interventions.

2012). Extended families collectively manage "shambas" (hereafter referred to as the "Homestead")—small plots of land with a cluster of houses and single homestead head (Carter 2012). Until the 1950s, the Giriama rarely engaged with fishing, however, recent estimates suggest the area contains 400–800 fishers, mostly fishing from dug-out canoes or on foot using hand-lines, gill-nets, seine-nets, spears and spear guns, poison, and fish traps (Carter 2012). There are recognized landing sites at Mida Creek but no formal Beach Management Unit to regulate fishing. Mida Creek may be representative of other ethnically similar fishing communities in Kenya, but not of more formalized Swahili fishing culture (for further information, see Cinner & McClanahan 2006).

Sampling protocol

We conducted a systematic survey of homesteads in villages bordering Mida Creek between 6/6/13 and 28/6/13. In the absence of a census, we worked with the AphiaPLUS Community Health Network (a U.S. Agency for International Development (USAID) funded health program) to identify the study population. Staff identified individual homesteads neighboring the creek in each village, which were then numbered. Numbers were picked from a bag to achieve a random sample of 50% of the homesteads in each village. Interviews were conducted with the senior family member(s) of 51 homesteads, providing information on a total of 1,008 people. Lead respondents for these households included 35 men and 16 women. Interviews were undertaken in the local dialect, Kirigama, using semistructured questionnaires and timelines (Bunce *et al.* 2000). One of the authors (KL), a locally born and well-integrated research assistant, conducted the interviews to minimize information withholding on this illegal and therefore potentially sensitive subject. Due to low levels of local enforcement and local advice that MNF is not a taboo subject, it was concluded that the effect of potential biases on over- or underreporting would be minimal. Indeed, people did not refrain from MNF in full view of the researchers. Local permissions for the survey were granted by the Chief's office at Gede, the Public Health Officer of Gede Health Clinic, and the chairman of the Mida Creek Conservation Committee. Questionnaires were piloted with input from three members of staff from a local non-governmental organisation (NGO), with no ethical issues raised. The research ethics protocol was approved through the Imperial College Conservation Science research ethics process, involving formal submission of a Research Ethics form, interview, and panel review and resubmission for panel approval. Interviewees were informed of survey aims and assured of anonymity and withdrawal rights.

Data analysis

Interview transcripts were processed by the field team to identify gaps and clarify answers in English. Qualitative responses were coded by the primary author and all statistical tests were performed in R v. 3.1.2, R Foundation for Statistical Computing, Vienna (R Core Team 2012) with a significance threshold of 0.05. Two measures of mosquito net use were calculated for each homestead; net availability (number of nets per person) and net coverage (proportion of residents sleeping under nets).

Results

Prevalence of MNF and relationship to bed net use

Of the 51 homesteads surveyed at Mida Creek, 48 fished locally, half of which used a mosquito net for fishing. Mosquito nets were the second most popular gear alongside larger mesh nets (>1″) and after hand-lines. Twenty-two of 48 MNF households listed prawns and/or juvenile fish as the main target catch, while 11 mentioned crabs, rays, and squid.

Mosquito nets were obtained in three ways: 84% of the homesteads received nets through mass distributions, 27% private sale, and 16% through targeted maternal health distributions. Ninety-two percent of MNF homesteads fished with old nets no longer deemed fit for beds. There was no significant relationship between the source of nets and whether they were used for fishing.

Mean availability of mosquito nets was 0.58 nets (S.E. 0.05) per person in MNF homesteads and 0.55 nets (S.E. 0.08) per person otherwise (T test, $n = 51$, $t = -0.34$, df = 43.90, $P = 0.73$). The mean proportion of people sleeping under an MN at night was the same for MNF and non-MNF homesteads (0.91, with S.E. 0.03 and 0.05, respectively).

Social and demographic make-up of MN fishers

Mosquito net fishers from respondent homesteads at Mida Creek were commonly described as adult men and children with one reference to an adult woman. Eighteen of 24 MNF homesteads stated that catch was consumed at home; 10 selling fish when surplus to domestic need; and three fished exclusively for sale. When asked what gears were used before mosquito nets were available, 11 of 24 of MNF households said they used larger nets not targeting small fish, four referred to *tandilo* fishing using cloths or sacks to catch small fish, while three said they did not fish at all before mosquito nets were available. Wealth, education, and occupational diversity had no effect on the likelihood of a family engaging in MNF.

Community perceptions of changes in fish abundance and MN use over time

Collective perceptions of fish stocks in the creek were of steady decreases in both abundance and size over the last 50 years (Figure 2). This held irrespective of gender. The earliest memory of mosquito net ownership was from the late 1970s. Growth in fisher numbers was the most common explanation for decreasing fish abundance from 25 of 51 respondents. Other explanations included human population growth, increased use of small mesh nets (including mosquito nets and ¼″ prawn nets) and other illegal gears, climate change, pollution, and habitat damage. Fewer explanations for trends in fish size were offered but largely referred to increased numbers of fishers and juvenile catch (Table 1).

Respondents ($n = 51$) were asked to describe up to three positive and three negative aspects of MNF (Table 2). The most common positive answers were ease of use, provision of food and livelihoods, and the efficiency and reliability of the method. Thirteen could see no positive aspects to MNF. The most frequent response described juvenile catch as negative, followed by removal of fish eggs and illegality. They also acknowledged potential ecosystem-level effects of toxicity and net discards. When asked how the community as a whole perceived MNF and recommendations for the future, 24 of 51 respondents described the community view as negative and stated that MNF should be discouraged with concerns about ecosystem health. Twelve emphasized the importance of MNF for livelihoods and food security. Respondent gender did not influence these results. A common recommendation for the future (12 of 51) was gear diversification, citing government help, investment, and gear exchanges as potential solutions.

Discussion

We found MNF to be locally common at Mida Creek, facilitated by health initiatives for continuous mass distribution of nets. However, our results suggest that impacts on malaria prevention are likely to be of limited concern at this site; mosquito net distribution efforts at Mida Creek have achieved a mean availability of one net between two people, with no apparent trade-off between MNF and malaria protection as fishers rely on old nets.

Community perceptions were predominantly of a degrading fishery at Mida Creek both in terms of fish abundance and size; however, current evidence gaps preclude definitive links to MNF. The interactions between MNF and other gears and fisheries (such as offshore commercial fisheries and large-scale shrimp fishing) are also likely to be complex. The community perceived both the actual

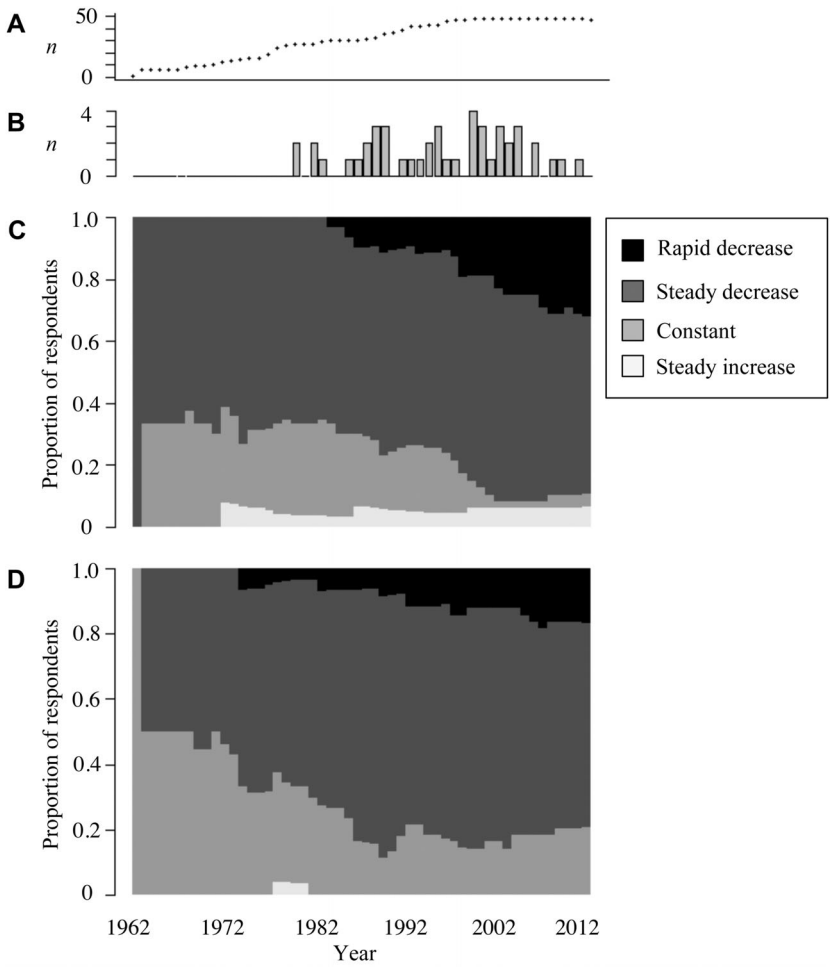

Figure 2 Community perceptions of change in fish stocks over time at Mida Creek from timeline activity. (A) n = number of respondents with memory of each year; (B) n = number of respondents reporting first use of MNs for malaria protection in each year; (C) proportion of perceived changes in fish abundance; and (D) proportion of perceived changes in fish size.

benefits of MNF—protein and enterprise—and the potential negatives of unsustainable exploitation.

Mosquito net fishers at Mida Creek commonly stated active targeting of small/juvenile fish and prawns, using old mosquito nets obtained for free, in shallow water (suggesting no requirement for competence at sea or access to vessels). In general, exploited fisheries show reductions in abundance, size, and trophic structure of fish (Jennings & Blanchard 2004), related to intensity and the types of fishing gear (McClanahan & Mangi 2004; Mangi & Roberts 2006). In the absence of stock assessments and estimates of size-specific fishing mortality at Mida, we cannot empirically assess sustainability. Fisheries management typically seeks to limit catch of immature individuals before spawning, avoiding growth overfishing by setting minimum legal mesh sizes (Vasilakopoulos *et al.* 2011). There is also an argument for preservation of large, fecund individuals and controlled use of selectively diverse gears to balance fishing mortality across species and sizes in proportion with natural productivity (Garcia *et al.* 2012). The exploitation of juvenile fish, where they are of subsistence or economic value, as part of a well-regulated balanced harvest may not be detrimental to overall sustainability. This is particularly a possibility in artisanal mixed fisheries (Law *et al.* 2012; Kolding *et al.* 2015), such as that of Mida Creek, although many coastal east African fisheries may lack the institutional capacity to effectively implement ecosystem-based management.

Almost half of the homesteads at our study site reported active MNF, usually among diverse livelihood strategies. While this result would suggest the study was not subject to underreporting or other biases, a suggestion supported by the opinions of local staff, there is a potential influence when requiring respondents to report on themselves or family members which should be considered when interpreting these results. Almost all respondents used old nets obtained for free, and fished in shallow water, on foot with a low skill requirement. Unlike

Table 1 Reasons given for perceived direction of change in fish stocks at Mida Creek

	Reason for change	Fish abundance (n^a)	Fish size (n^a)
Social/demographic	**– Decrease**		
	More fishers	25	9
	Population growth	8	1
	Poverty	2	0
	+ Increase		
	Fewer fishers	1	0
	Management interventions	2	0
Fishing methods	**– Decrease**		
	Small mesh nets (including MNs)	8	1
	Fishing gears	7	3
	Illegal fishing methods	6	1
	Targeting juvenile fish	0	7
Environmental	**– Decrease**		
	Climate change	7	0
	Pollution	3	1
	Habitat damage	2	3
	+ Increase		
	Replanting of mangroves	1	0
	None / do not know	9	22
	Did not answer	2	2

[a]number of respondents.

Note: Respondents ($n = 51$) were asked to describe the direction of change in fish stocks within the time span of their memory and to offer reasons for these.

Table 2 Perceptions of mosquito net fishing (MNF) at Mida Creek

	Good things about MNF	n^a	Bad things about MNF	n^a
Catch	Nets are good for catching small fish	7	Nets take juvenile fish	23
	Nets are good for catching prawns	7	Nets remove fish eggs	11
	Nets do not damage catfish (Ngogo)	2	Nets take indiscriminate by catch	4
			Other	2
Habitat	Nets provide shade for fish	1	Nets become litter	5
			Toxic insecticide in water	5
			MNF destroys the habitat	2
Use	Nets are easy to use/reliable catch	12	Nets are not recommended / legal	13
	MNF provides food / livelihood	10	Nets are difficult to use, much drag	1
	Nets are available/cheap	3	Nets tear easily	1
	Making use of / recycling nets	2		
Other	No good things	13	No bad things	2
	Do not know / did not answer	11	Do not know	12

[a]number of respondents.

Note: All respondents ($n = 51$), including nonfishers, were asked to list up to three good things and three bad things about MNF.

the Muslim Swahili community with intergenerational transfer of fishing skills, the Giriama are traditional agriculturalists only entering the fishery in recent decades (Carter 2012). More than half of MNF homesteads at Mida Creek either had no history of fishing or of targeting small fish prior to gaining access to mosquito nets. MNF is a viable entry-level activity, which may be contributing to the increasing density of fishers and unreported and unregulated fishing on the east African coast (Obura 2004; Muthiga *et al.* 2008).

Mosquito nets are generally used as seine nets operated by two or more people, fishing from shore, in a range of habitats including mangroves, estuaries, seagrass beds, intertidal mud and sand flats, rocky areas, or reef platforms. It is a relatively unskilled, low investment fishing practice undertaken by nontraditional fishers. MNF has also been

reported in freshwater fishing communities, particularly the great lakes, and outside the region (e.g., Manase *et al.* 2002; Srivastava *et al.* 2002; Minakawa *et al.* 2008; Banek *et al.* 2010).

It is possible that MNF is practiced wherever mosquito nets are available (Gurung 2015). The conservation problem of fishing with mosquito nets is multilateral and cross-disciplinary. It will need an interdisciplinary approach to design effective interventions. Mosquito nets are a potentially valuable asset for poor households for whom livelihood diversification may reduce vulnerability to shocks (Hughes *et al.* 2005; Béné 2009). Therefore, a better understanding of how MNF fits into overall livelihood strategies is needed, rather than simply implementing bans and excluding fishers from management. As the first study of the prevalence and context of MNF in a coastal area, this study begins to inform the debate on its social and ecological impacts. We hope that it will promote stakeholder collaboration and further investigations into the role of MNF within fisheries management, rural livelihoods, and coastal ecosystems.

In order to guide local, national, and international policy (Figure 1), further research should focus on the role of MNF in livelihoods and subsistence among a broad range of communities. Do people engage in MNF opportunistically; because MNF fills a specific niche in livelihood strategies; because catch is particularly valued for consumption; to satisfy market demand; or because of a lack of alternatives? Does MNF detract from antimalarial coverage in scenarios where socioeconomic circumstances differ? Ecosystem-level impacts of MNF need urgent investigation to implement appropriate management while avoiding negative socioeconomic effects. Additional concerns for investigation include environmental toxicity and increased insecticide resistance when nets are retained (Norris *et al.* 2015). Who should take responsibility for safe disposal of nets remains a pertinent issue in countries where millions of nets are being distributed with an effective insecticidal life span of 4–5 years (Guillet *et al.* 2001).

If MNF is common and widespread, facilitates new entrants to fisheries, and targets juvenile fish, then natural resource managers will be justifiably concerned, but careful thought needs to be given to top-down enforcement as a method for management, particularly in communities which may lack alternatives and/or enforcement capacity. Community led, inclusive and/or comanaged solutions may be the more effective option.

Acknowledgments

We are grateful to the Tropical Agriculture Association (award to EB) and the Natural Environment Research Council (award to RS) for financial support. We thank A Rocha Kenya, CORDIO, Benjamin Cowburn, and Dawn Goebbels for their logistical support and advice. Research was conducted under Research Permit Number: NCST/RRI/12/1/BS/205, National Council for Science and Technology, Kenya. EJMG acknowledges support from a Pew Marine Fellowship and NERC. Datasets are available from the first author on request.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Figure 1. Observations from Key Informant interviews with experts throughout coastal East Africa.

Table 1. Sites and sources of Key Informant observations.

Figure 2. Characteristics of fishing activities among households surveyed at Mida Creek.

Table 2. Insignificant nonparametric tests of the effect of sociodemographic indicators on MNF behavior among households ($n = 51$).

Figure 3. Example timeline from homestead survey.

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