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Challenging assumptions: the gendered nature of mosquito net fishing and the implications for management

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ABSTRACT

Mosquito net fishing (MNF) is a growing activity globally, particularly in places where mass distributions of nets are a public health policy to tackle malaria. Due to the mesh sizes used, and therefore its assumed 'indiscriminate' nature, MNF is thought to be unsustainable and a threat to both fisheries resources and biodiversity. As a consequence, MNF is widely illegal. While a body of evidence is growing as to the scale of MNF, few detailed case studies exist and none explicitly address the assumptions of ecological harm. Here, we present a first full characterization and gear comparison for MNF within the small-scale fisheries of Cabo Delgado, Northern Mozambique. The assumptions of harm to the fishery are challenged by the characterization of MNF as highly gendered in this case; with a primarily androcentric deployment method posing some risk to the fishery but a predominantly gynocentric method demonstrating possibility of limited resource overlap with other gears and little evidence of ecosystem-level impacts. The gendered nature of the fishery is discussed in terms of both risks and benefits to the fishery, with a critical need for further socio-economic assessment identified in order to guide more effective and equitable management of MNF.

Introduction

There is increasing documentation of the use of mosquito nets as fishing gear, particularly where they are provided for free in anti-malaria efforts (Larsen, Welsh, Mulenga, & Reid, 2018; Short, Gurung, Rowcliffe, Hill, & Milner-Gulland, 2018). The rapid growth of this activity is perceived to have negative impacts including conflicts and concerns about further growth as mass distributions of mosquito nets continue to expand (Gettleman, 2015). Though the scale of this 'misuse' has been challenged as overstated (Eisele, Thwing, & Keating, 2011), generally the use of mosquito nets in small-scale fisheries (SSFs) is seen to be a risk to both biodiversity and food security. First, mosquito net fishing (MNF) is thought to contribute to both growth and recruitment overfishing due to their small mesh size and therefore assumed indiscriminate nature (McLean et al., 2014); leading to high levels of juvenile capture, generally avoided under a selective fishing management paradigm (Sissenwine & Shepherd, 1987). Additionally, the nets' ready availability, lack of requirement for capital investment and ease of use is thought to increase numbers of fishers and therefore overall pressure on SSFs (Short et al., 2018).

Concerns also exist over anti-malarial efforts, as a net used for fishing is one not being used for personal protection from mosquitos (Gettleman, 2015). The media often reports MNF as an activity of the very poor, engaged in out of desperation or due to declining catches and a lack of alternative livelihoods. In responding to MNF, it is therefore important to understand how feedbacks between health, environment and livelihoods manifest themselves in individual communities. However, current policies have been adopted without this understanding. While numerous countries attempt to tackle MNF through enforcement-based responses (Bush et al., 2017), these remain almost entirely lacking in evidence, being advocated for based on the social and ecological assumptions outlined above. These policies have therefore been criticized (Short et al., 2019), with a need to determine the actual impacts of MNF on fisheries and associated biodiversity for more effective policy development.

Few MNF studies use empirical data (Jones & Unsworth, 2019; Manase, Mwenekibombwe, Namoto, & Mponda, 2002; Mulimbwa, Sarvala, & Micha, 2019). A study of the Clupidae fishery of Lake Tanganyika estimated MNF larval harvesting of *Limnothrissa miodon* to have opportunity costs of $2.1 million (Mulimbwa et al., 2019). However, a relationship between wet weight of harvested juveniles and potential wet weight of harvested adults is assumed regardless of population dynamics; all MNF use is assumed to be the same; and opportunity costs are investigated solely for male fishers; this omission is of particular importance as female MNF has been suggested to be frequent (Short et al., 2018). A recent effort by Jones and Unsworth (2019) was the first to assess catch composition and juvenile capture for a tropical reef fishery in Northern Mozambique, positing a substantial removal of juvenile individuals across a range of seagrass-associated species and asserting proof of unsustainable fishing practices. However, the study is narrow in scope (being based on the same two fishers over just 25 catch events), again limited to male catch and effort, and the assertions as to sustainability and food security impacts are extended from the data presented.

There is a crucial need to better understand the nuances of gender in natural resource exploitation, including fisheries (Fortnam et al., 2019; Kleiber, Harris, &

Vincent, 2015), in order to improve management and ensure better equity in line with Sustainable Development Goal 5. Gender marginalization is an additional level of marginalization which can perpetuate poverty (Béné, 2003) and poor understanding of gender-specific fishing has led to the exclusion of women from management (Harper, Grubb, Stiles, & Sumaila, 2017). Addressing the needs of women in natural resource management is increasingly seen as essential for development (Bennett, 2005). Indeed, marine conservation projects failing to do so have been accused of institutionalizing inequitable access to fisheries, failing due to issues such as gendered spatial management, which is restrictive to women (Baker-Médard, 2017). Efforts to include women in co-management have also suffered from 'gender evaporation', whereby engagement is lost over time as barriers to participation are not addressed (Harrison, 1997). Kawarazuka, Locke, McDougall, Kantor, and Morgan (2017) recognize a failure to explicitly include the nuances of gender in socio-ecological systems research and suggest methods for better integration of gender theory and methodologies into wider analyses. It is therefore critical to ensure that research into MNF and subsequent policy development explicitly address female use.

Here, we investigate the aforementioned assumptions of harm to fisheries as they pertain to the reef fisheries of Palma and Mocímboa da Praia districts in Cabo Delgado Province, Mozambique. We explore the role of MNF in socio-ecological systems by providing an in-depth look at the activity for a specific location, testing some of the ecologically relevant assumptions of risk posed by MNF, through a gendered lens, by addressing the following questions:

1. How, by whom and where is MNF conducted in Cabo Delgado?
2. Does MNF increase pressure on stocks and habitats?
3. Is MNF indiscriminate and a threat to the fishery?
4. Does MNF compete with other gears for resources?
5. What role does gender play, and what implications does this have for management?

Methods

Case study site

Cabo Delgado is a biodiversity hotspot with healthy reefs of national and regional importance, recommended for World Heritage status (Obura, 2012) alongside the most extensive mangroves in the region (Pereira et al., 2014). However, it is threatened by extractive activities such as removal of coral for building material (Rosendo, Brown, Joubert, Jiddawi, & Mechisso, 2011) and recent oil and gas exploration, as well as increased international and domestic fishing pressure. As a consequence, fish populations are in decline (McClanahan & Muthiga, 2017; Samoilys et al., 2011). Local fishing pressure is also expanding as traditional fishing-farming communities redistribute effort due to reduced agricultural productivity (Rosendo et al., 2011).

The marine fisheries of Cabo Delgado include mixed subsistence and artisanal fishers exploiting the large intertidal, shallow reef and shallow-pelagic resources along the mainland and surrounding islands of the Quirimbas archipelago (Fortnam et al., 2019).
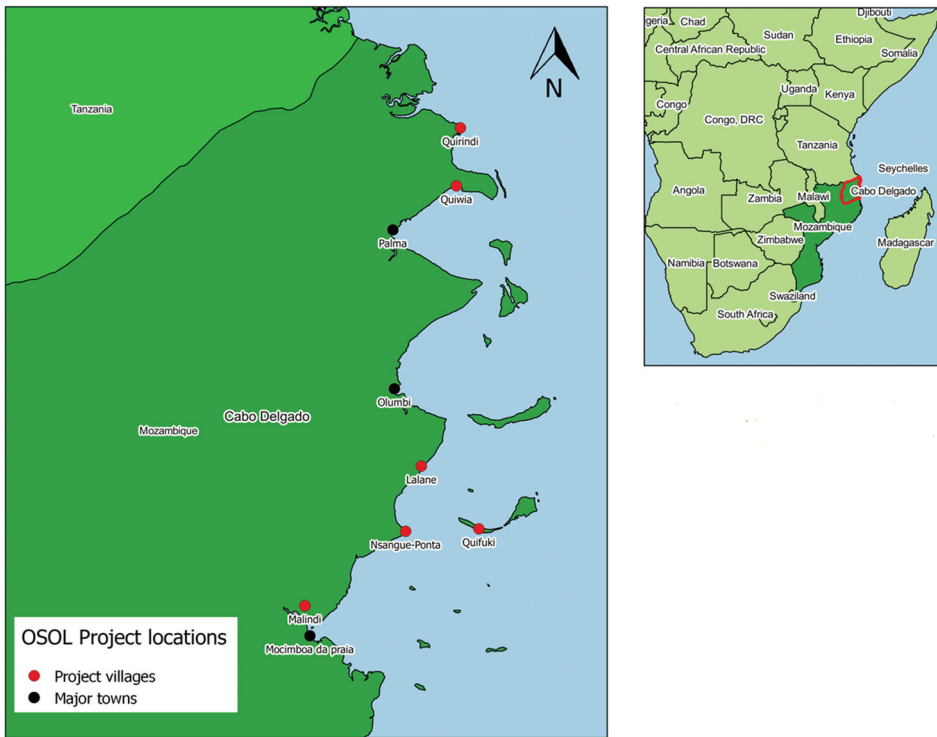
Figure 1. Map of study sites in Cabo Delgado, Northern Mozambique.

Cabo Delgado is a poor, isolated and understudied region of Mozambique where fisheries are limited mainly by access to gears; with little commercial activity (Garnier et al., 2008). There are limited in-depth studies of the fishing communities and ecology of the region, mainly focusing on the island communities of the Quirimbas archipelago (da Silva, Hill, Shimadzu, Soares, & Dornelas, 2015; Gell & Whittington, 2002; Samoilys et al., 2011). MNF is known to be particularly prevalent in the region, with Samoilys et al. (2019) reporting engagement rates of up to 42% of fishers in some villages, and a regional rate of 27%; the highest of any gear in this mixed coral reef fishery. Although governing bodies are aware of significant MNF activities in the area, monitoring has not been established.

Devolution of power to communities has been enacted in recent years, in large part due to conflicts arising over complex issues such as the increasing use of fine-mesh nets such as MNs (Menezes, Smardon, & de Almeida, 2009). Despite this, national legislation on mesh size is utilized to discourage MNF (Boletim da República, 2013) and local officials have indicated that prison sentences may be introduced for law-breakers (IIP Regional Director, Pers. Comms.). This has led to significant concern over potential dependencies on the activity by vulnerable individuals, and negative reactions to confiscation of MNF gears.

This research was part of the Our Sea Our Life (OSOL) fisheries co-management project, delivered by the Zoological Society of London and partners. Ethical approval was granted through the Imperial College Research Ethics Committee. Ref: 15IC3005 10/11/2015.

Methodological approach

A mixed methods approach was used to conduct a rapid characterization of the mixed artisanal fisheries inclusive of MNF. This was intended to be broadly investigative due to the dearth of background information on MNF available. Data collection was conducted by the lead author and in-country staff. Data were collected from all six villages associated with the OSOL project (Figure 1). Site characterization interviews were conducted with the leaders of each site prior to the start of the study, revealing strong similarities in fishing activities. While cultural and physical differences do exist between sites which may influence the fisheries, for the purposes of this study information was pooled for analysis to give a broad overview of the region.

Focus groups

Focus group discussions (FGDs) were conducted at all sites between March and December 2015. Wherever possible, gender-disaggregated groups were recruited and translation performed by local staff. In three meetings (Lalane, Quiwia and Malinde) a male 'chaperone' local to the village was required for female FGDs and were instructed not to influence the group by interjecting. A detailed protocol and briefing were provided to translators prior to meetings. Neutral community areas were used for FGDs, with soft drinks provided to attendees. A total of 37 women and 22 men were actively involved in FGDs, all of whom were recruited by local staff prior to the meetings as people with knowledge of MNF activities.

Participatory mapping

Mapping was conducted with fishers in each community to identify predominant fishing zones in the intertidal, reef and subtidal, alongside predominant gear use and resource availability in each. Groups of fishers were predominantly male; however, the presence of a female fisher was ensured for each map. Maps were drawn freehand by in-country staff, using google maps as a guide. Local landmarks such as important buildings, infrastructure (e.g., telephone masts), offshore islands and tidal currents were used to orient fishers. Fishers discussed until reaching consensus, fishing ground names were then cross-referenced with existing landing site data to ensure all were accounted for. Any later discrepancies were clarified using focus groups.

Timelines

Timeline FGDs were held with female MN fishers in the villages of Quirinde and Malinde; having the highest prevalence of MNF. Recruitment focused on obtaining a range of ages and fishing experience. Fishers were oriented by identifying temporal landmarks such as local history, political history, memorable events such as food shortages and flooding, arrival of NGOs and industry (oil and gas). The starting point was chosen as independence from Portugal, and each FGD had at least one attendee with a personal memory of this. Fishers were asked to discuss and describe memorable

changes in (a) numbers of people using MNs to fish and (b) relative size of fish catches.

Landings data collection (rapid assessment)

Landings data were collected by village technicians, employed by the OSOL project and trained in fish identification, between the start of September and end of December 2016 as part of an intensive, detailed catch assessment within longer-term efforts. Surveys were conducted weekly during neap tides, and twice weekly during spring tides for a minimum of 4 h. Landing sites and beaches were patrolled by technicians, and all fishers sighted were surveyed upon arrival. Owing to the particularly informal nature of landing sites in this region and the high possibility of missing returning fishers, conclusions as to total fishing intensity are not within the scope of this investigation.

Technicians recorded total catch weight and total species weights and abundance. using subsamples and extrapolation where necessary. Species identification was conducted in-situ and, due to time and capacity, crustacea and mollusks were not identified. Where identification was uncertain, photographs were taken and local names recorded for later identification. MN catches can contain very large numbers of individuals and monitoring was subject to time constraints. Therefore, where necessary, abundance was calculated using an average of individuals for the relevant gear, as opposed to visual estimates. Number of fishers, gender, time fishing, gear type, vessel type and fishing ground information were recorded.

Targeted juvenile composition surveys

Additional landing site data were recorded specifically for female MN fishers by RS and a dedicated member of in-country staff. Data collection followed the same protocol as above in order to remain comparable, however juvenile composition was additionally assessed. Following composition analysis, up to 10 randomly selected individuals of each species were measured for their total length. Data were collected between January 2016 and April 2017. Extension of these surveys to male fishers was largely not possible due to sensitivities around male MNF (described in the results).

Analyses

Length at first maturity (L_m) and length-weight relationship co-efficients ($W = aL^b$) data were obtained from FishBase for the species recorded. Catch per unit effort (CPUE) was calculated as catch per fisher, per hour. The per hour effort measure was used to account for highly variable fishing times, particularly between men and women, allowing a better estimate of soak time.

Differences in CPUE between gears were analyzed using Generalized Linear Models owing to the non-normal distributions of the data.

Statistical analyses were performed using R 3.5.0 (R Core Team, 2014).

Figure 2. Example of women fishing with the Kutanda method. Nets may be sewn together but are otherwise unmodified. Fishers may fish in groups of three or four (with either one or two chasers) up to around waist-deep water on sand flats and seagrass beds.

Results

Characterization: a highly gendered fishery

FGDs, observations and participatory mapping with both men and women reveal a strong distinction between two main modes of deployment for MNF: Kutanda and Chicocota. These methods are highly gendered, with women mostly deploying MNF as Kutanda and men as Chicocota. Differences between the methods spanned physical characteristics of the gear, time, tide, species and habitat preferences. Here, we provide a brief description of these two main methods in order to provide context for the stratification used further in analyses. More detail is provided in the Supplementary material (Text S1).

'Kutanda'

The word Kutanda previously related to a traditional form of fishing mainly conducted by women using cloth, now used to describe the predominantly female form of MNF. More broadly throughout East Africa this practice may also be referred to as 'Tandilo' fishing (Bush et al., 2017). Single MNs or several stitched together are used in a seining method in shallow, open waters over sand and seagrass. Groups of three or four women will seine toward shore and herd fish using splashes, before depositing their catch into a container and beginning again (Figure 2). Predominant species cited as targeted with Kutanda were quite specific, with all focus groups indicating that juveniles were most targeted:

- 'Sala' = *Gerres oyena*, the Common silver biddy.
- 'Mingalare' = *Hyporhampus affinis*, the Tropical halfbeak. This name sometimes refers to *Strongylura incisa*, the Reef needlefish, also commonly caught.
- 'Safi' = Various species of Rabbitfish, predominantly *Siganus sutor*.
- 'Sololo' = Various species of Emperor, predominantly *Lethrinus variegatus*.
- 'Ncundadji' = Various species of Goatfish, predominantly *Parapeneus macronema*.
- 'Sardinha' = Various species of Clupidae, rarely distinguished between.

Collectively, mixed catches of small fish from MNF are referred to as 'Medada' (meaning small mixed fish).

'Chicocota'

Chicocota is the predominantly male method of MNF meaning 'to drag'. There is some ambiguity between Kutanda and Chicocota in certain communities, and more northerly sites may use the name 'Mukuelele'. Chicocota differs from Kutanda in both net design and deployment. Multiple MNs are sewn together, usually more than for Kutanda, and additional layers of stronger nets are added to the bottom (Figure 3). Chicocota is operated by four or more men, attaching themselves via looped ropes due to the force necessary for seining, and nets are deployed over reefs, in deep water and even from boats (Figure 3). Individual catches are reportedly much larger (also see Figure 4). Information as to target species was often nonspecific, save for a desire to target shrimp, and highly mixed reef species which may or may not be juveniles.

The social norms of Northern Mozambique and indeed many African SSFs, alongside time restrictions and childcare duties which disproportionately impact female fishers, tend to restrict engagement of women in primary fishing activities largely to gleaning. However, the advent of Kutanda, and specifically the increased efficiency of MNF, have reportedly bridged this exclusion due to their ready use in intertidal environments. In Cabo Delgado, women are restricted to the three gear types most closely associated with intertidal fisheries (Supplementary Figure S4): spears (handheld), harpoons and mosquito nets. This segregated space use is supported by participatory maps with fishers in the intertidal area exclusively portrayed as female (Supplementary Figure S8) and through reported fishing zones from landings data (Supplementary Table S1). Although fishers mapped gleaning resources,
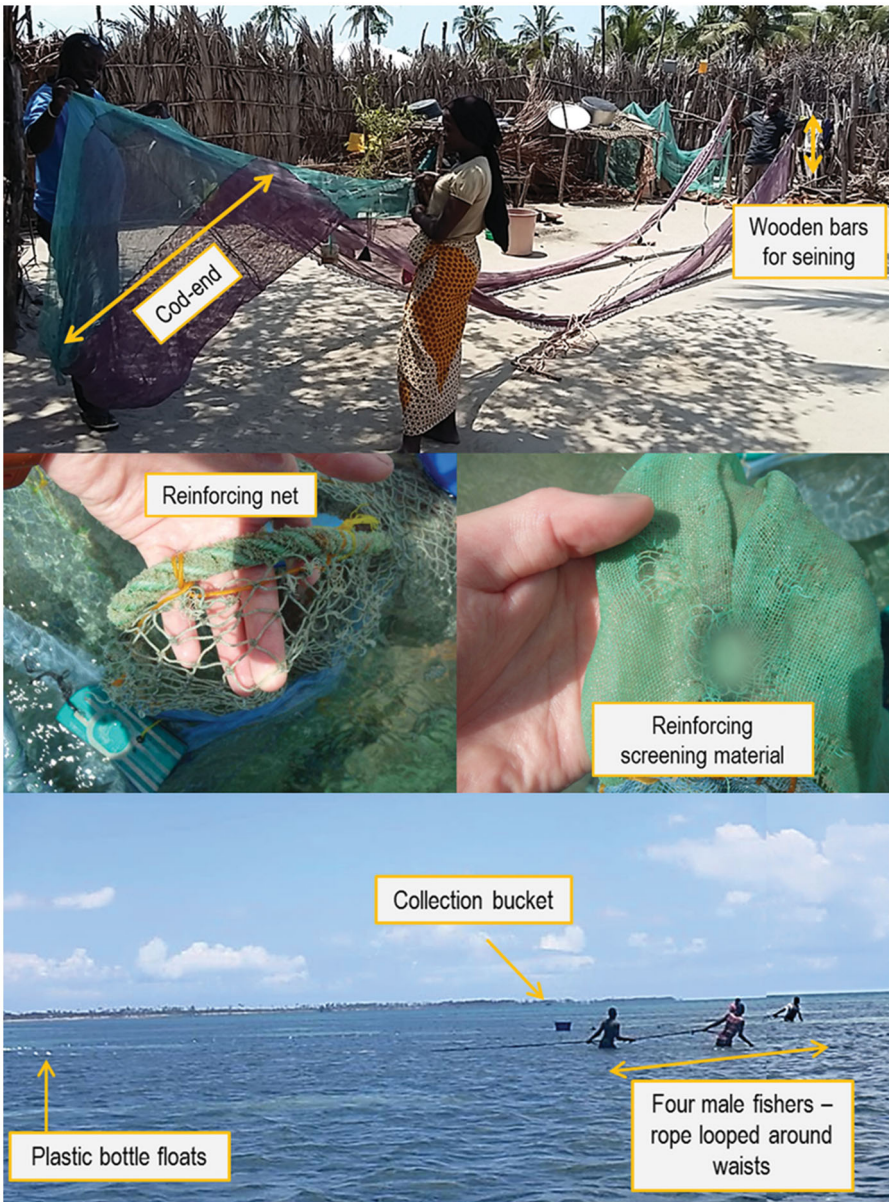
Figure 3. Example of a medium-size Chicocota net (top) and reinforcing done for use over reefs (center). Example of male Chicocota fishing activity over a fringing reef (bottom).

the activity was rarely included without prompting, as gleaning is often not considered 'true' fishing.

Perceptions from both men and women revealed a strong taboo attached to Chicocota. This gear has attained a highly damaging reputation, while Kutanda remains comparatively socially acceptable. These distinctions viewed together demonstrate a critical need to disaggregate our analyses by gender. The rest of these results therefore address the issue of MNF as a two-gear, gendered issue.
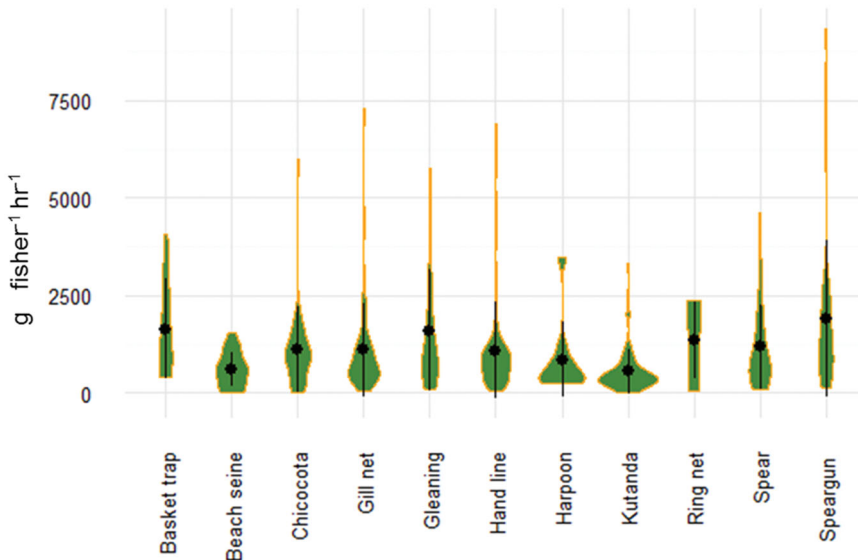
Figure 4. Violin plot showing distribution of CPUE values across predominant gears. Black dots and lines are mean values with standard deviations. GLM comparing CPUE between gear types: Adjusted R-squared $= 1$, F-statistic $= 8.313e + 12$ on 10 and 370 DF, p-value $= < 0.005$. Gleaning is included in this comparison but excluded from later species-level analyses where only gears predominantly targeting fish were included.

The scale of MNF

Timelines described an overall increase in numbers of people engaging in MNF over time since independence (Figure 5), with fishers indicating a rapid increase since the distribution of free nets for malaria control. Initially, this led to a perceived rise in individual catches, owing to increased efficiency. However, fishers' perceptions were then of rapid decreases in individual catches, alongside a change in fish sizes, resulting in what they consider to be a current crisis.

> Last year there were no fish, we caught very little. I don't know if the size of fish has changed, only that we never catch a big fish now. (Female respondent, FGD Lalane)

This increase in MNF prevalence included a process of conversion to Kutanda from the use of traditional cloth fishing gear, and uptake of Chicocota methods by local men, as opposed to just encouragement of new entrants to the fishery.

> There have always been Kutanda fishers, I can't remember when, we have fished since childhood with Kapulana [cloth skirts]. Before these nets were free we could buy them from Tanzania. (Female respondent, FGD Lalane)

> We have too many sons. What can they do? We never ate [Moray] eel before, now we do. They didn't use Chicocota before, now they will. (Female respondent, FGD Quirinde)

> Our only important [fisheries] resource is [MNF]. For us we are not so practiced at catching octopus and the crabs are not for money. (Female respondent, FGD Quirinde)
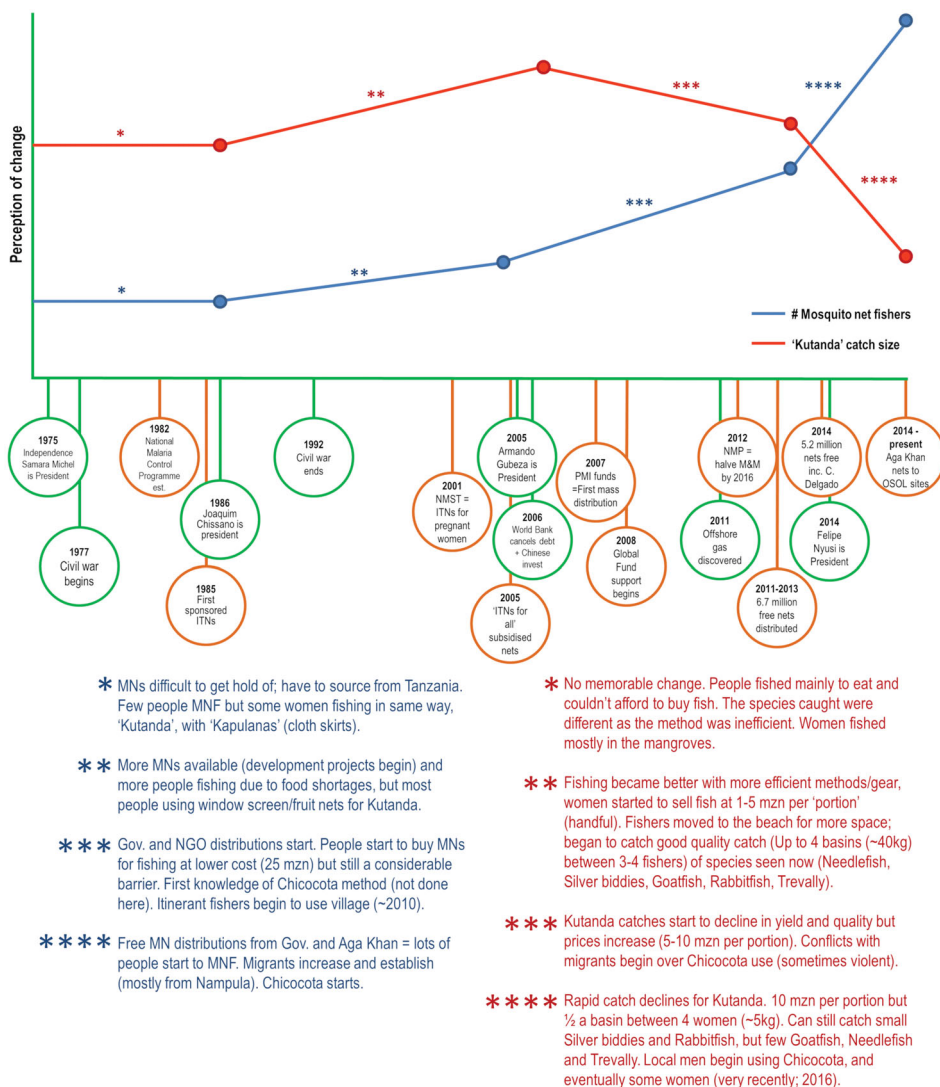
Figure 5. Combined timeline FGD details from female fishers in the larger villages of Malinde and Quirinde.

The overall increase in MNF engagement was also partly attributed to a rapid rise in migrant fishers, blamed by resident populations for the introduction of the Chicocota. However, it is also suggested that these migrants are resented for their use of 'better' gears (owing to access to capital for gear purchase), meaning larger catches. While no evidence of MNF by migrants at OSOL sites was recorded in rapid assessment data or through observations, it was commonly thought that women accompanying their husbands regularly MN fished.

A comparison of MNF CPUE with the predominant legal gear types of the region showed significant differences (Figure 4). Speargun had the highest mean CPUE at 1.9 kg (SE +/− 0.29) per fisher per hour, and Kutanda the lowest at 0.55 kg (SE +/−

Table 1. Summary values for gear diversity comparison, with darker shading representing larger numbers.

Gear	Number of observations	No. spp. in total	No. spp. making up 80% landed weight	No. spp. making up 80% abundance
Gill net	47	106	24	31
Speargun	43	78	17	25
Basket trap	6	37	16	16
Spear	22	53	14	17
Beach seine	23	51	10	12
Chicocota	28	58	13	5
Harpoon	5	7	13	2
Hand line	63	62	2	2
Ring net	7	3	2	2
Kutanda	60	45	1	1

0.27) per fisher per hour. Chicocota had an average CPUE of 1.1 kg (SE +/− 0.48) per fisher per hour, ranking 6th of 11 gear types.

Habitat use

All coastal habitats were identified as potential fishing zones for MNF. Respondents perceived some negative impact of MNF seining methods in both subtidal (from Chicocota) and intertidal (from Kutanda) habitats, added to increased rates of trampling in delicate areas such as seagrass beds and coral reefs. A preference for MNF use in these habitats, but differing zone use between male and female fishers, was confirmed by landings data (Supplementary Table S1). Male Chicocota fishers reported using subtidal fishing zones 41% of the time, and intertidal zones with coral reefs 34% of the time. Conversely, female Kutanda fishers reported predominant use of intertidal areas, regardless of habitat, 83% of the time, and offshore island sites 7% of the time. Female Chicocota use, which FGDs and landings data identified as rare but increasing, occurred in intertidal zones. The majority of female Kutanda use occurred on foot (97%) and the majority of male Chicocota use by canoe (62%) (Supplementary Figure S1). Two occurrences of motorboat use by women both involved Kutanda and reflect use of offshore islands.

It may be noted that gendered distinctions in CPUE extend beyond MNF deployment types, with female fishers still catching fewer fish than male fishers when using Chicocota (Supplementary Figure S5), reflecting the fishing zones used. Lower male than female Kutanda catches, mindful of the very low sample size ($n = 2$), may support FGD indications that this method is only used by elderly or disabled males and children.

Catch diversity

A total of 238 species were recorded in the rapid assessment time period (Table 1). Kutanda and Chicocota ranked in the lower to middle position in terms of number of species recorded (7th and 4th of 10, respectively). The most species-rich gear was gill nets (106 spp.), the least was ring nets (3 spp.), though sample size for the latter was low.
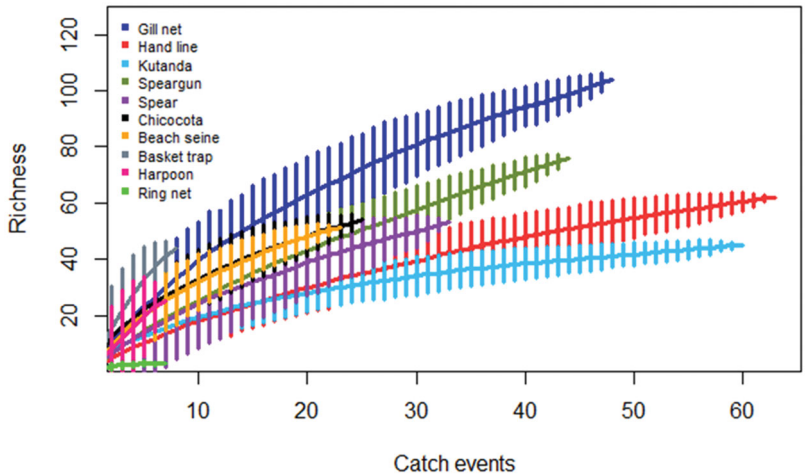
Figure 6. Species accumulation curves from catch events (numbers of fishing trips) for each gear.
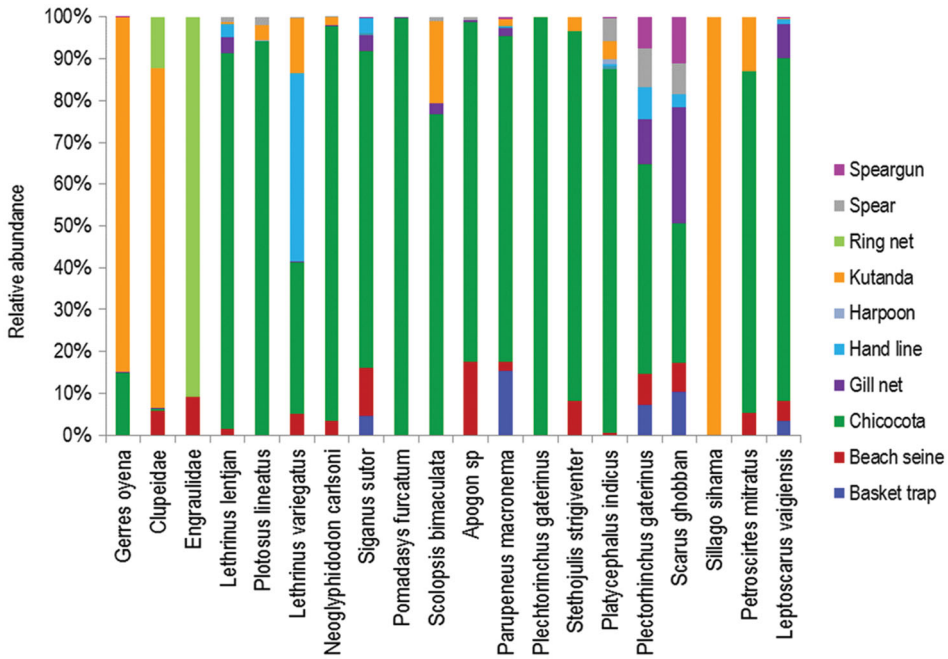
Figure 7. The top 20 species (ranked left to right) by relative abundance and the proportional representation of each gear in the catch for each species.

Species accumulation curves demonstrate distinct variability in catch diversity (Figure 6), with gill nets and spearguns most species rich and Kutanda the least besides ring nets (which are highly targeted with a very small sample size). Chicocota sits in the mid-range of this spectrum. Though these curves indicate that the rapid assessment may not have detected the full range of species for some gears, Kutanda estimates appear to be robust.

Catch composition

Figure 7 shows the top 20 most caught species across the whole fishery, ranked by abundance (number of individuals caught) and the contribution of each gear toward total offtake, adjusted for sample size. Species are a mixture of reef and pelagic-associated species, though it should be noted that 84% of the total individuals were *Gerres oyena*, followed by 5% Clupidae, the remaining species each comprising ≤1% of individuals. Kutanda and Chicocota both catch high numbers of individuals, but their influence is segregated. Chicocota dominates capture of 15 of the 20 species, indicating a broad reach across species. The high offtake of *Sillago sihama* (Silver sillago) is exclusively from Kutanda, and the high relative catch of *G. oyena* from Kutanda (the most abundant species in the overall catch by a large margin) is marked. Overall, catches are clearly dominated by small-bodied species (Clupidae and Engraulidae) and individuals (juvenile *G. oyena*).

The species of importance to each gear are explored by ranking the species making up 80% of the catch for each gear by landed weight (Supplementary Figure S6). These results support those above in suggesting that Kutanda catches have little overlap with other gears in terms of species of importance, with *G. oyena* the only species listed (at 87.5% of the catch) and only additionally of importance to Chicocota (8% of catch). However, Chicocota catch shows some significant species overlaps with other gears e.g., *Siganus sutor* is the second most landed species for Chicocota (9.5%) and is additionally important to gill net (6%), basket trap (7%) and hand line fishers (7%).

MNF and juvenile capture

For Kutanda, total length data supports the idea of a tendency for capture of small fish. Though comparisons with Chicocota cannot be drawn from catch data, FGD responses suggest that both gears catch similar sized individuals. The majority of individuals caught by Kutanda were under 10 cm. The average length recorded across 48 species, was 7.15 cm (SE $+/-$ 0.007, $n = 1130$), with the smallest 1.3 cm (*G. oyena*) and the largest 43 cm (*Hyporhampus affinis*). Individuals >15 cm were rare and dominated by *H. affinis* and *Strongylura incisa* (Supplementary Figure S7).

The proportion of each species larger than the length at first maturity (L_m) reveals that the assumption of high juvenile capture largely holds, with just five species having mature representatives (Supplementary Figure S7): 0.9% of *G. oyena* were over L_m ($n = 458$), 20% of Clupidae ($n = 94$), 57% of *H. affinis* ($n = 21$), 25% of *Petroscirtes mitratus* ($n = 16$), and 67% of *Amblygobius phalaena* ($n = 3$). Significant adult capture was therefore limited to *H. affinis* and *A. phalaena*, with the former also highlighted in FGDs as important to Kutanda fishers due to its size and consequent value. *H. affinis* not only tends to school in shallow waters but also has an extended needlelike rostrum which can get caught even in small mesh sizes, supported by fishing observations. The remainder of the species were represented only by individuals below L_m.

Of the *G. oyena* catch just four mature individuals were recorded. As this species makes up 88% of the Kutanda catch by weight and 93% by abundance this indicates that the vast majority of Kutanda catch is of juveniles of this single species. While

length at first maturity values can be inaccurate, with an average length of 6.2 cm (SE $+/-$ 0.15) the majority of *G. oyena* are well below L_m.

Discussion

In the present study, we provide an in-depth characterization of a MN fishery for the first time, revealing a gendered fishery in terms of gear and potential impact. We then use empirical data to challenge prevailing assumptions about MNF of particular importance in critical assessment of current policy. While we highlight a need for more localized research to enhance understanding of MNF, the lessons learned are widely applicable, particularly throughout East Africa (Bush et al., 2017).

Is MNF increasing pressure on stocks and habitats?

The assumption that MNs may attract new entrants to the fishery is both supported by the data presented here and challenged as an over-simplification. Fisher perceptions indicate a significant increase in use of MNs for fishing within the Cabo Delgado region (Figure 5) which supports Samoilys et al.' (2019) findings that show that across the OSOL sites mosquito nets are now the most commonly used gear. However, it is difficult to translate this directly to increased pressure on the fishery due to numerous factors, including tradeoffs with time spent on other gears.

MNF has been shown to be a productive gear in the context of the fishery as a whole, with CPUE for Chicocota being comparable to gears such as hand lines. Alongside perceived catch declines for other gears this may be driving the rise in use of Chicocota by men, serving as a fallback option for existing fishers as well as an entry point for new and inexperienced fishers. For women who traditionally engage in gleaning activities, being largely marginalized from the wider fishery, MNs may increase the efficiency of their activities and allow them to access new resources/species, despite CPUEs for Kutanda being lower than those for other fishing gears. Women in fishing communities may already be time-poor, trading off household duties alongside those of agriculture and daily food needs. MNF may be an important activity which can fit in with other commitments, particularly farming; requiring just a few hours of a day to provide a meal (average fishing time for Kutanda was 3 h and 44 min [SE $+/-$ 6 min]). Additionally, agricultural decline is increasing the importance of fisheries, particularly for the time-poor, which may drive these changes.

This local rise in MNF is accompanied by a perceived decline in individual catch, though causation cannot be inferred. Generally, Mozambique SSF total catch is thought to be declining. Catch reconstructions by Jacquet, Fox, Motta, Ngusaru, and Zeller (2010) for Mozambique suggested declines of ~32% between 1986 and 2005 attributed to increasing fishing pressure pre-dating mass distribution of MNs, though the reconstruction failed to include Cabo Delgado due to data restrictions. Direct conclusions for the region are therefore difficult. While the rise of MNF in Mozambique may have been a reaction to individual catch declines, it is impossible to disaggregate its role in subsequent declines. Certainly, the suggestion that Chicocota is now rapidly increasing in popularity is of concern; though any level of fishing will cause changes

which are not necessarily unsustainable, the professed decline in women's individual MNF catches is troubling. Additionally, the focus of Kutanda on a single species generates concern for its future. However, this decline in individual catch is matched by a perceived increase in fisher numbers; therefore, overall landings may be consistent as individual catches decline. Without efforts to overcome the barriers to effective, catch data collection it is difficult to corroborate these perceptions. It will be important to incorporate MNF into monitoring efforts, and to carry out a stock assessment of *G. oyena*.

This study is not able to assess the footfall pressure of MNF on sensitive ecosystems, but the professed increase in fisher numbers and shift to more open habitats suggests increased trampling is likely occurring in key habitats. Additionally, while Kutanda impacts may be limited by their fragility, the specific adaptations to Chicocota for use over complex substrata suggests potential for damage to coral reefs and seagrass beds. Physical damage to reefs requires prolonged periods of recovery and can have longstanding knock-on impacts. Seagrasses are particularly vulnerable to this type of damage. The huge importance of seagrass beds to fisheries, and their use worldwide particularly by SSFs, is only recently being fully realized (Unsworth, Nordlund, & Cullen-Unsworth, 2018). The seagrass beds of Cabo Delgado are demonstrably diverse and important, particularly for some of the species highlighted here as key catch components e.g., *Siganus sutor, Leptoscarus vaigiensis, Lethrinus variegatus, Lethrinus lentjan* and *G. oyena* (Gell & Whittington, 2002). The highly connected nature of these habitats as nursery and spawning grounds means knock-on impacts from the current and future use of Chicocota in particular are a legitimate concern (Unsworth et al., 2008).

Is MNF an indiscriminate method?

Legitimate concerns have been raised as to the impacts of MNF on ecosystems due to their use in sieving broad swathes of water, with mesh sizes usually ∼3 mm. Our results suggest that rather than indiscriminate, MNF may actually be a highly selective method compared to legal gears. Certainly for Kutanda with the vast majority of its catch being comprised of just a single species; *G. oyena*. With Chicocota there is some cause for concern. Though it is not the least selective gear in the fishery, our observations suggest its relatively high CPUE, combined with a broader species range and high catch abundance, requires urgent assessment. Interestingly, beach seines showed lower CPUE than Chicocota with a similar diversity of catch. Given the level of concern over beach seining throughout this region of Africa and elsewhere leading to tight restrictions (McClanahan & Mangi, 2001), regulation of Chicocota may be appropriate.

In terms of maturity status of fish in the MNF catch, this study was only able to investigate landings from Kutanda fishers. As with diversity, it is erroneous to describe this gear as indiscriminate. Indeed Kutanda appears to select effectively for juveniles. What this juvenile capture means for sustainability of MNF is difficult to infer in the absence of full stock assessment. Such catch is largely considered detrimental under the traditional size-selective management paradigm, as Kutanda is harvesting individuals both before they can breed and before reaching their growth potential. In a

scenario of particularly heavy fishing this could lead to recruitment overfishing, whereby numbers of juveniles extracted are so high as to limit subsequent populations, (Sissenwine & Shepherd, 1987), as well as growth overfishing where the rents/ food security potential of the catch is not realized (Law, Kolding, & Plank, 2015). Excessive harvesting of a species in nursery habitat such as seagrass beds can have knock-on effects for subsequent adult life stages in different ecosystems, such as on coral reefs. Therefore any ecosystem-level impacts through disruption of food webs may be manifested across a range of aquatic habitats (Unsworth et al., 2008). Here we are unable to support or refute this possibility, but it is important to acknowledge this risk and incentivize appropriate monitoring.

However, the high intensity fishing required for these impacts is thus far not supported for MNF. Conversely, harvesting of juveniles in appropriate quantities may be of significant benefit to fishers under balanced harvest theory, which posits that we currently do not draw enough on the productive early life stages of fish, or harvest a wide enough diversity of species (Garcia et al., 2012; Zhou et al., 2019). In a balanced harvest scenario, which some SSFs may naturally follow (Plank, Kolding, Law, Gerritsen, & Reid, 2017), different species and life stages are harvested according to their productivity. The 'free lunch' scenario, where models fail to account for smaller fish eaten in order for larger fish to grow (Kolding & van Zwieten, 2011), is explicitly corrected. Contrary to selective fishing which seeks to limit both size and species caught, balanced harvest may also fit better in cultures such as Cabo Delgado where a wide range of gears are employed and anything is suitable for the pot (Plank et al., 2017). Evidence shows that negative impacts of selective fishing, namely population size truncation, removal of the productive BOFFFFs (Big, Old, Fat, Fecund, Female Fish), and early maturity may be avoided by diversifying catch (Law & Plank, 2018). The early loss survivorship strategy of fish with naturally high juvenile mortality means potential for recruitment overfishing from juvenile harvest may be of significantly lower risk than from removal of mature females which compromises spawning capacity (Kolding & van Zwieten, 2011).

The feasibility and validity of balanced harvest remain hotly debated, particularly outside of these low-intensity SSFs (Pauly, Froese, & Holt, 2016). However, given that MNF seems to fill a separate niche within an existing mixed fishery, it should not be labeled as unsustainable based on evidence of juvenile capture alone. From a food security perspective, balanced harvest with juvenile capture aligns with the Ecosystem Approach to Fisheries Management goals of maintaining ecosystem integrity and prioritizing fisheries yields for food security, rather than maximizing rents (Kolding, Jacobsen, Andersen, van Zwieten, & Giacomini, 2015; Plank, 2018).

In the case of *G. Oyena*, the level of juvenile capture may be particularly high, and given that adults appear a minimal target for other gears the approach to this species specifically may not be considered fully 'balanced' and therefore remains of some concern. More evidence is necessary on total catches and how MNF (and its multiple forms) fits into the size-stage spectrum of fishing methods (Plank et al., 2017). It is critical for the debate on these management techniques to remain open.

Does MNF compete with other gears?

MNF in Cabo Delgado is at the center of many conflicts between fishers, authorities, public health bodies and other resource users. However, when it comes to direct competition between Kutanda, Chicocota and legal gears we have presented little evidence of conflict. Kutanda is of concern from the perspective of *G. oyena* stocks, but although this species is of marginal importance to gillnet fishers it barely registers within catches of other gears. The robust targeting of juveniles means there is little competition for adults. As a highly productive species with a high resilience to fishing and low vulnerability to extinction (using FishBase estimates, Froese & Pauly, 2018), it is questionable that current levels of Kutanda fishing are likely to greatly impact the species.

Chicocota shows more overlap with targets of legal gears, though again this is limited compared to overlap between legal gears. Species which may need further investigation due to capture by Chicocota include: *Leptoscarus vaigiensis, Siganus sutor, Lehtrinus lentjan* & *variegatus*. These are commercially important species for local male fishers.

In terms of fishing zones and potential competition for space at the local level, our data again question the assumed impact of female MN gears on the wider fishery. Participatory mapping and landings data for all sites highlighted the restricted use of intertidal zones by Kutanda fishers. These results further highlight the MNF gender divide in habitat use, with shallow water habitats used by women, and increasing male Chicocota use with increasing depth and complexity of habitat. It is not possible to know whether this habitat use is entirely by choice, for example to be close to home as a women's adaptive strategy allowing both productive and reproductive work (de la Torre-Castro, Fröcklin, Börjesson, Okupnik, & Jiddawi, 2017), a women's preference for specific resources, or forced by social-norms of a gendered division of labor. Either way, in this case our data support the conclusion that while men using Chicocota may compete for fishing grounds and fish with other male gears, women's Kutanda use competes neither in a spatial sense, nor in a cultural sense by threatening androcentric activities and livelihoods or 'reinforced masculinity' (de la Torre-Castro et al., 2017).

Implications for gendered fisheries management

While there are obvious food security and livelihoods benefits to MNF (Gettleman, 2015; Larsen et al., 2018; McLean et al., 2014), these have previously been considered short term, marginal and unsustainable. Some of the evidence we present begins to counter this, suggesting Kutanda poses limited threat to other gear users and shows promise in sustainably harvesting a resilient species at a particularly productive life stage (Kolding et al., 2015) as a significant and relevant contributor to food security both locally and further afield.

As existing stakeholders in the fishery, the enhanced access to resources for women provided by MNF is arguably a step toward social equity in an otherwise skewed system, where androcentric management can devalue both women's roles and the contributions of intertidal resources (de la Torre-Castro et al., 2017). While increased access

may contribute to overarching unsustainable pressure on the fishery, an argument can be made that under typical co-management goals of representativeness and inclusion, Kutanda MN fishers deserve recognition within management processes rather than blanket exclusion. Cabo Delgado has the highest rates of childhood stunting and malnutrition in Mozambique (Lopus, 2015). Women with access to fisheries resources have been shown to provide better childhood nutrition than households exclusively dependent on male provisioning (Harper, Zeller, Hauzer, Pauly, & Sumaila, 2013). Combined with a growing body of evidence for the nutritional benefits of consuming small-bodied fish (Bogard et al., 2015; Thilsted, James, Toppe, Subasinghe, & Karunasagar, 2014), it is important to acknowledge the broader positive impacts MNF may have. Concerns for MNF follow a Malthusian narrative which may have driven a deliberate ignorance toward the health, wellbeing and social equity benefits that MNF may provide.

de la Torre-Castro et al. (2017) highlight the importance of understanding women's roles across a generalized seascape in order to better characterize the importance of different coastal zones to incomes and subsistence toward effective marine spatial planning. Current failures to do so result in androcentric management that perpetuates inherent inequities. MNF has a real relevance to these recommendations as an activity linked to multiple zones, and a unique mixed gender engagement with differing strategies. It will be particularly important to include women in governance structures and management planning where increased female Chicocota use is observed. This may add to the risk that *G. oyena* is fished at unsustainable levels and could additionally extend pressure to other species. Excluding the primary actors from management planning may only serve to obscure the drivers and impacts of MNF leading to policy failures and disenfranchise a large subset of fishers from co-management efforts.

Fisheries are highly variable, and there is evidence from elsewhere that 'Kutanda'-style fishers are not always predominantly women (Bush et al., 2017). There are likely to be large differences between marine and freshwater systems such as the African Great Lakes, where the scale of MNF has caused alarm (McLean et al., 2014) but where small fish are also potentially underutilized as a means to meet food security needs (Kolding et al., 2019). Case studies in such locations should be a priority.

This study was subject to a number of limitations. A gap lies in the seasonality of the rapid assessment which, despite straddling the seasons, is not fully representative. However, we are confident in the validity of the results which substantiate, in good detail, fishers' qualitative reporting of species caught. Additionally, the results corroborate year-round data collected as part of the OSOL project over several years (Samoilys et al., 2019) which was unfortunately not suitable for this level of analysis. We therefore feel that our data suggest that, in this case, the assumptions underpinning current prohibition of MNF are potentially incorrect. However, it remains vital to distinguish between Kutanda and Chicocota in terms of the risks they pose. In addition, the potential to miss returning fishers means we are unable to estimate total catch and MNF prevalence, something requiring urgent quantification.

Conclusion

Generally, our case study demonstrates the need for a concerted, rigorous and widespread investigation of MNF in the context of broader fisheries management. A pertinent question arising from these results is how they might compare with other case studies in other locations, particularly freshwater environments. It is clear that the lack of monitoring, justified by MNFs' illegal status, has led to the adoption of widely questionable assumptions. Incorporation of MNF into monitoring efforts and management should be incentivized if these knowledge gaps are to be filled. Women must be recognized as crucial actors within the fishery, with recommendations for better gender disaggregation for data collection being particularly important in an MNF context. Finally, MNF is a key livelihoods issue with potential community-level impacts on food security and incomes. Interventions therefore need to holistically address MNF inclusive of the risks, current contributions and future opportunities it may represent.

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