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Escape gaps in African basket traps reduce bycatch while increasing body sizes and incomes in a heavily fished reef lagoon

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ABSTRACT

There is increasing effort to develop fishing methods that increase sustainability of the fishery and reduce bycatch without sacrificing the incomes of fishers. Consequently, we explored the use of modified African basket traps (experimental traps) retrofitted with 4 cm × 30 cm escape gaps and compared their catches with those from unmodified traps lacking these gaps (controls). Studies were undertaken in a heavily fished Kenyan coral reef lagoon dominated by sand, seagrass, and coral reef. Of the 1202 fish captured, we distinguished 64 species from 23 families with significant differences in catch composition between the two trap types. Among the bycatch, numbers of butterflyfish and other low value species were reduced in the experimental traps. Overall, at the trap level, there were no significant differences in terms of mean length, weight and value of the target species. Nevertheless, fish captured in experimental traps were 31% longer and 55% heavier and a decline in the capture of low value species accounted for the lack of difference at the whole trap level. Due to a strong size–price relationship in this fishery, there was a 25% increase in the economic value of the gated compared to control traps.

1. Introduction

Catch of coral reef fish, even at an artisanal scale, can lead to severe changes in fisheries ecosystems (McClanahan et al., 2008). Many of these adverse ecological impacts result from a high bycatch of juveniles and species with ornamental or ecological value that are not desirable as food (Thomsen et al., 2010). The harvesting of these reproductively immature fish and suboptimal sized individuals can reduce fisheries biomass and productivity and reduce the prey of carnivores (Hicks and McClanahan, 2012). Furthermore, continuous capture of ornamental and other narrow-bodied species can reduce the attraction of reefs to ecotourism activities because many recreational divers consider species diversity a key attraction (Parsons and Thur, 2008; Suuronen et al., 2012). Consequently, there is a need to consider alternative fisheries methods that reduce these potential detrimental impacts.

In Africa and globally, fish traps are widely used to target reef fish in coral reef lagoons (Stewart, 2007; Johnson, 2010). Although trap fishers typically target high value fish, such as groupers and snappers (Stewart, 2007; Johnson, 2010), standard traps are weakly selective and retain most fish that enter, resulting in the capture and mortality of many non-targeted species (Munro, 1983). Consequently, high bycatch of juvenile fish and non-target species can reach >50% of the catch, even with relatively low fishing effort (Hardt, 2008). To date, bycatch remains a common impact of trap fisheries and reducing it is a key concern for increasing fishery sustainability and ecosystem-based management (Johnson, 2010).

Gear modification efforts initially focused on the use of larger mesh sizes to sustainably manage, regulate and control bycatch in the trap fishery (Munro et al., 2003). Nevertheless, given the diverse morphologies of fish caught by traps, it is still impossible to select a mesh size that optimizes the yield of all exploited species (Robichaud et al., 1999). For example, mesh large enough to permit escape of narrow-bodied, low-value fish, such as butterflyfish, would also permit escape of high-value target species, such as snappers (Bohnsack et al., 1989). In fact, in the Caribbean, Johnson (2010) showed that inserting a larger escape mesh into a small meshed trap reduced the mean number of fish and the value of the catch compared to a trap with a standard mesh. Additionally, the multi-species and multi-gear nature of reef fisheries coupled with the resource users' poverty and dependence on fishing complicates efforts to prevent negative ecological and social impacts of gear modification (Cinner et al., 2009a).

Subsequent fish trap modification efforts used narrow escape gaps as an alternative (Baldwin et al., 2002; Munro et al., 2003; Johnson, 2010). However, this approach is yet to come up with

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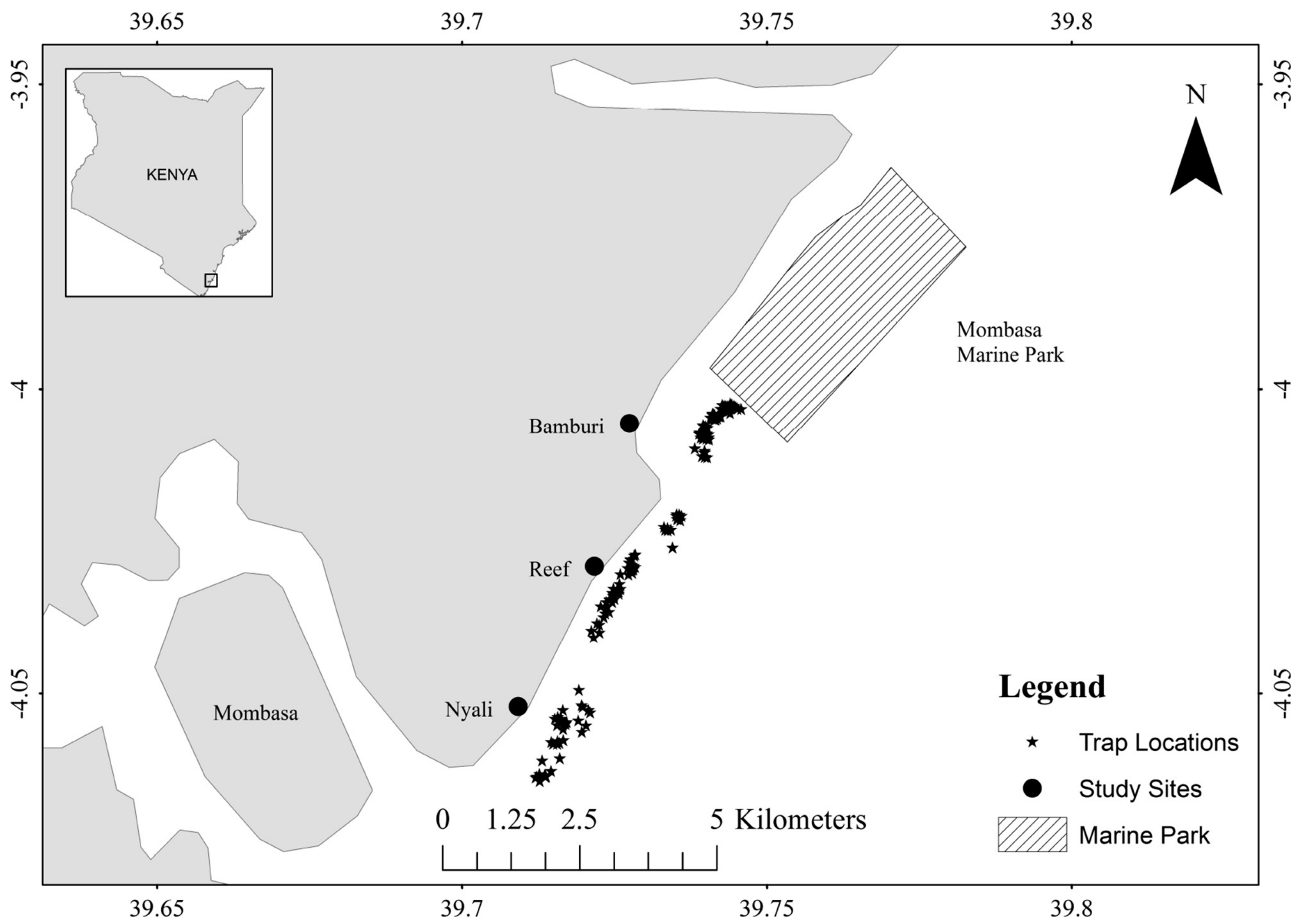

Fig. 1. Map of the study area and locations where traps were deployed in the Mombasa Marine National Reserve.

fishery-specific gap sizes that can reduce detrimental effects without diminishing the incomes of fishers. Consequently, studies have recommended experimental surveys to ascertain gap-size effectiveness in species diverse trap fisheries due to the temporal and spatial variations in species and size structure composition (Johnson, 2010; Munro et al., 2003). Therefore, we explored the use of standard African basket traps retrofitted with escape gaps in a heavily fished Kenyan reef lagoon. Escape gaps were expected to increase fishery selectivity, control catch composition and thereby promote greater ecosystem-based management and sustainability (McClanahan and Cinner, 2008; Cinner et al., 2009b). While escape gaps were predicted to reduce the catch of narrow-bodied, compressible, bycatch, and juvenile fish (Johnson, 2010), we also predicted that gaps would reduce fisher incomes and reduce their willingness to adopt them. Therefore, we evaluated the prices and potential incomes of fishers using the two different trap designs.

2. Materials and methods

2.1. Study sites

The study area extended from the southern border of the Mombasa marine park (S4.001280°, E39.741740°) to the fished reefs in Bamburi and Nyali (S4.063740°, E39.712090°) (Fig. 1). Traps were placed in back reef along the fringing reefs at locations selected by an experienced trap fisher but placed haphazardly within these locations (Fig. 1). Benthic habitats differed somewhat in terms of benthic cover, rugosity, reef slope and the other gear use, but habitats were connected such that there were not obvious differences in potential fish species composition. Nevertheless, fish biomass estimates in this back reef, while low compared to unfished reefs, was higher than the most heavily fished reefs in Kenya (McClanahan et al., 2007).

2.2. Trap use and design

An experienced trap fisher constructed six traps (3 control and 3 experimental). The traps were handmade and, therefore, differed slightly in exact dimensions, but all trap volumes were ~0.2 m^3. Iron made frames, and manila rope weave (hexagonal mesh, aperture 4.5 cm high by 4.5 cm wide) was attached to all sides of the traps with sisal ropes. The entrances were down curving, tapering cylinders with a horse neck shape that prevented the escape of fish through the entrance. A side panel to extract captured fish was affixed to the frame of each trap using cable ties. To maintain the (4 cm × 30 cm) dimensions of the gaps, metallic-iron gap frames were used. Escape gaps were left open throughout the experiment on both sides of the V-shaped trap ends. To optimize catch for consumption, Mahon and Hunte (2001) recommended a minimum mesh aperture of 5.1 cm but 4.5 cm is commonly used in Kenya. Traps were deployed from a small boat or canoe and held on the bottom by large stones or corals. Once deployed, traps were usually left overnight (24-h soak time) and the captured fish were checked and removed the following day. Fishers replenished the bait and then reset the trap in the same or nearby place depending on the catch. An observer checked the trap contents while snorkeling before lifting the trap out of the water. Once captured fish were observed, the traps were removed from the water, and captured species were further identified and the total length and weight of each fish recorded by a ruler and triple-beam balance (Lieske and Myers, 1994) (Fig. 2).