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Artisanal fisheries on Kenya's coral reefs: Decadal trends reveal management needs

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ABSTRACT

Kenya's small scale coral reef fisheries are extensively studied yet a practical understanding of the resilience and status of the main target species remains largely elusive to the manager. We combined a range of fishery and fish population descriptors to analyse Kenya's coral reef fish and fisheries over a 20 year period from the 1980s, to determine the sustainability of current fishing levels and provide recommendations for management. Fishers reported over 13 different artisanal fishing gears of which there are data for only the five widely used gears. Average catch rates declined 4-fold from the mid 1980s (13.7 ± 1.6 kg/fisher/trip) to the 1990s (3.2 ± 0.1 kg/fisher/trip) and then stabilized. Species richness in catches of these historically multi-species fisheries declined dramatically and by 2007 only 2–3 species appeared in the top bracket (65–75% by number) with *Siganus sutor* (African whitespotted rabbitfish) and *Leptoscarus vaigiensis* (marbled parrotfish) consistently being in this bracket in beach seine, gill net and basket trap catches, contributing up to a maximum of 45% and 47% of the catch, respectively. *Lethrinus borbonicus* dominated handline catches (50%). Relatively stable catch rates are reported from the 1990s to the mid 2000s, likely maintained by shifting proportions of species in the catches. Patterns in fish population densities over time show National Parks have helped increase densities of Lethrinidae and Haemulidae and reduced the decline in densities of Scaridae and Acanthuridae, but that National Reserves have had no positive effect. We suggest that the National Parks, which are No Take Zones (NTZs), and the fisheries regulations inside and outside of Reserves are inadequate for maintaining or restoring reef fishery target families under current levels of fishery exploitation. We propose that recruitment overfishing of several species and insufficient areas under full protection, all exacerbated by climate change, are contributing to driving Kenya's artisanal coral reef fisheries to a tipping point. We recommend species–specific management options, changes in and enforcement of gear regulations and many more effective NTZs are needed urgently if these fisheries are to continue to provide livelihoods and food security on the Kenyan coast.

1. Introduction

Small-scale artisanal coastal fisheries can provide up to 99% of the protein source to coastal households, provide over 80% of households' income and therefore play a key role in food security in developing countries (Barnes-Mauthe et al., 2013; Foale et al., 2013; McClanahan et al., 2013). Despite this, they are frequently undervalued by developing countries' national policies (Henson and Winnie, 2004; Hardman et al., 2013; Aloo et al., 2014). Further, artisanal fishers operate largely to earn cash but also for subsistence, both of which are poorly quantified (Obura 2001; Ochiewo, 2004; Cinner et al., 2009a). Consequently their contribution to national income and livelihoods is poorly acknowledged.

Small-scale artisanal coastal fisheries are characterised as being multi-gear, multi-species and landed at multiple landings sites, as seen in Kenya (Kaunda-Arara et al., 2003; McClanahan and Mangi, 2004) and typical of many tropical fisheries around the world (Munro and Williams, 1985; Wright and Richards, 1985; Dalzell, 1996). This makes them difficult to monitor and manage. If monitoring is done it frequently only records total landings without fishing effort, making the data almost meaningless (Luckhurst and Trott, 2009). Further, problems of overfishing and the use of destructive fishing methods in these fisheries are now widespread and generally linked to poverty, over-population and poor governance (Allison et al., 2009; Gutiérrez et al., 2011).

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Coral reef fisheries are extensively studied small scale artisanal fisheries with many cases of over-exploitation (Russ 1991, 2002; Newton et al., 2007), yet management reference points and an applied understanding of the resilience of coral reef fishes to exploitation remain largely elusive to the fisheries manager on the ground. These fisheries contribute a substantial portion of Kenya's artisanal catches (Government of Kenya, 2008, 2012) and also represent one of the most studied in a developing country (Kaunda-Arara et al., 2003; Mangi and Roberts, 2007; McClanahan et al., 2010; Hicks and McClanahan 2012) providing a valuable source of data and information. Yet our understanding of the status of these fisheries and defining their most suitable management options remains challenging.

For decades researchers have tried to understand the contribution of fin-fishes in terms of annual marine production or yield from coral reefs (Marten and Polovina, 1982; Munro and Williams, 1985; Russ, 1991; Dalzell, 1996). It is evident that reef yields >5 mt km^{-2} yr^{-1} are possible, with the highest productivity (>20 mt km^{-2} yr^{-1}) reported from reefs in Philippines and American Samoa (Craig et al., 1993; Maypa et al., 2002).

In this study we examined Kenya's coral reef fisheries over two decades to provide practical management advice, to estimate their annual yield and to contribute empirical evidence to recent debates on management options such as conventional gear and size limits controls (Jennings et al., 2001; Hicks and McClanahan, 2012) and spatial closures such as MPAs (Roberts and Polunin, 1991; Jennings, 2009). We sought to determine the sustainability of artisanal fishing gears, their deployment and effort and also provide definitions of the gears. Specifically, we tested the following hypotheses that are frequently stated by fishery stakeholders in tropical fisheries: i) artisanal fishery catch rates are in decline and stocks are overfished; ii) populations of reef fish are declining.

We used a series of meta analyses to combine a range of fishery and fish population descriptors and parameters, both dependent and independent of the fishery, to assess the status of Kenya's coral reef fish and their fisheries from the 1980s to the 2000s, based on published (e.g. Samoilys, 1988; Watson et al., 1996; Kaunda-Arara et al., 2003; McClanahan and Mangi, 2004; Mangi and Roberts, 2007; McClanahan et al., 2007; McClanahan and Hicks 2011) and unpublished data (e.g. Carrara and Coppola, 1985; Coastal Oceans Research and Development Indian Ocean (CORDIO) unpubl.). Multiple data sources including estimates of fish population abundance that are independent of, but in combination with, fisheries data are important when trying to understand these complex fisheries (Connell et al., 1998; Daw et al., 2011). We examined trends in catch rates and fish population abundance, species composition of catches and yields and juvenile retention rates of different gears to understand gear impacts and the sustainability of current fishing levels.

2. Methods

2.1. Study sites

Kenya's coral reefs occupy the shallow inshore zone, extending offshore to <45 m depth, and at a distance of 0.5 km to ∼2 km from the shoreline, except where river systems enter the sea (Obura et al., 2000). The coast is contained administratively within five Counties, formerly six Districts (Fig. 1). A wide range of study areas have been reported, from small localised studies to the whole coast (Table 1). Based on the geography of the coast the commonly reported study sites were grouped into the following six locations (N to S): a) Kiunga-Lamu, b) Malindi-Watamu, c) Mombasa, d) Diani–Chale, e) Gazi and f) Shimoni (Fig. 1). The four districts (Lamu, Malindi, Mombasa, Kwale) reported by Carrara and Coppola (1985) were assigned to the first four of these locations. Sufficient data for long term CPUE trend analysis were only available for two locations: Mombasa and Diani-Chale.

A spatial overlay of nationally gazetted protected areas exists (Fig. 1) comprising four Parks and five Reserves (Table 2). To examine impacts of protective management we allocated data to one of three management zones: Parks (NTZs), Reserves and all other areas called "Fished" which are not protected and are fully open to fishing. It should be noted that the enforcement of Parks and Reserves is variable, though Parks are considered well enforced since the mid 1990s (Table 2; McClanahan et al., 2007).

2.2. Data collation

Published papers and some unpublished reports on fishing, fisheries and fishes on the Kenya coast were reviewed to extract key variables on fin-fish for assessing long term changes in Kenya's artisanal fisheries (Table 1). Catch per unit effort (CPUE) was used as a measure of the state of each fishery, where fishery refers to an artisanal gear. We defined as artisanal those gears used by local fishers within territorial waters, limited to within 12 nautical mile of the shore (GoK, 1989). These gears span those made from natural fibres that have been used traditionally for decades, to more modern gears involving man-made materials (Glaesel 1997; Samoilys et al., 2011a).

Papers that presented fishery-independent measures of fish population density from underwater visual census (UVC) surveys, were used to assess long term trends in population abundance of the species taken by artisanal gears, to provide a fishery independent measure of stock status.

A total of 23 papers and reports published between 1985 and 2012, documenting fisheries from 1984 to 2007 were used to extract key CPUE and catch composition variables and independent UVC estimates of fish density (Table 1). Where values were not specified in the paper but only presented graphically, values were obtained using Data Thief lll software (Tummers, 2006) to one decimal point. A nine year (1998–2006) dataset (CORDIO unpubl.) on artisanal fisheries (only data for fin-fish) in one location, Diani-Chale, including UVC estimates of population abundance, was also added and used to define certain parameters (see below). In most cases variables were estimated from means reported in papers and therefore their precision may have been inflated.

2.3. Standardisation of variables and statistical analyses

Inevitably, reviewing a wide range of papers spanning many years encountered different methods, units and presentation of results. Therefore standardisation of variables was necessary. Some papers lumped all species together for UVC estimates of fish densities or CPUE, or aggregated locations and were therefore excluded from the analyses. The following sections describe the parameters that were standardised and their statistical analyses. We cleaned the data, ignored uncertain estimates or aggregated data and were conservative in our calculations to minimise errors.

2.3.1. Fishing gears and years

Based on sufficient sample sizes across locations and years, data on five gears were analysed: large basket traps (∼6 cm mesh size), gill net, handline, speargun and beach seine. Where possible data were extracted by year collected. Where data were not presented annually the median for the study period was taken to represent the year of the data.

2.3.2. CPUE

The catch rate unit was standardised to kg/fisher/day for each of the five gears (one day is equivalent to one fishing trip – fishers