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Coral reef fish community life history traits as potential global indicators of ecological and fisheries status

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ABSTRACT

The productivity and diversity of coral reefs is being threatened by a number of human disturbances that could be better understood and managed with appropriate indicators. Here, I evaluated 9 biomass-weighted fish life history trait metrics and 4 categories of biomass (total, fishable, target, and non-target) using a large single-observer census of fish communities in 449 Indian Ocean reef sites. Comparisons and changes across a full gradient of fishing effort were made and fish traits compared between long unfished benchmark reefs (n = 62 sites) and reefs with variable fishing effort (n = 387 sites). I hypothesized that traits would differ between fished and the unfished benchmark sites and, as biomass increased, asymptotically approach benchmark values. Most weighted traits responded as predicted but variation among biomass categories, traits, and their responses to fishing and biomass was variable. For most traits, predictions for the total and fishable biomass fit better than target and non-target categories. Further, length-based traits were among the best indicator of status where as some commonly used traits like age-at-first maturity and trophic level were poor or responded contrary to predictions. Using multivariate analyses of all 9 traits did not strongly increase the predictive ability. Consequently, I suggest that geography, a large range in fishing pressure, and the inherent complexity of reef fish communities explains the variability better than the trait-specificity. Nevertheless, convergence between biomass and length-based traits occurred and suggest trait stability at an unfished biomass ~1000–1200 kg/ha. Biomass and length-based traits may have the broadest use in estimating sustainable fishing while other traits are unlikely to have global benchmarks. Thus, future research will need to account for spatial variation in environmental forces and fishing disturbances when using life-history traits. The practice of focusing on temporal responses to disturbances in comparable environments is recommended for impact studies.

1. Introduction

Coral reefs are being exposed to a number of environmental and human stresses and disturbances that are potentially undermining their ecological health and fisheries production (Cinner et al., 2016). One of the main solutions to many of these problems is to promote sustainable fishing that use indicators that respond well to changes in fishing pressure and reef ecology (McClanahan et al., 2015). Metrics, such as fish biomass and coral cover, are common means to evaluate reef condition but communities are expected to change in ways that are not fully reflected by these simple metrics (McClanahan and Graham, 2015; Bruno and Valdivia, 2016; Nash et al., 2016). Consequently, it behooves reef investigators and managers to examine other potentially useful indicators, particularly metrics that relate most directly to fisheries, their yields, and sustainability – key concerns of coral reef stakeholders in poor tropical countries (Hicks et al., 2013).

Coral reef fish and fisheries are complex multispecies communities influenced by a number of environmental, habitat, and food web dynamics (Nash et al., 2015; Graham et al., 2017). Communities are expected to change as biomass is reduced by fishing but the predictability of these changes and how to effectively measure change can be better understood (McClanahan, 2018a). Fish life history metrics, such as growth, size, life span, and mortality, are common ways to evaluate species level status for recovery from fishing and harvesting criteria (Worm et al., 2009; Coleman et al., 2015). Yet, species-level data are often missing in fish and fisheries studies and more holistic community metrics are often regarded as among the best indicators of fishing pressure (Nicholson and Jennings, 2004; Fulton et al., 2005; McClanahan and Hicks, 2011). Consequently, given the largely non-specific capture of coral reef fishes, an alternative approach is to weight life histories proportional to the community biomass of each taxonomic group (McClanahan and Humphries, 2012).

Life history traits weighted by the biomass of taxa or functional groups have been used to evaluate the trophic levels of fisheries (Pauly

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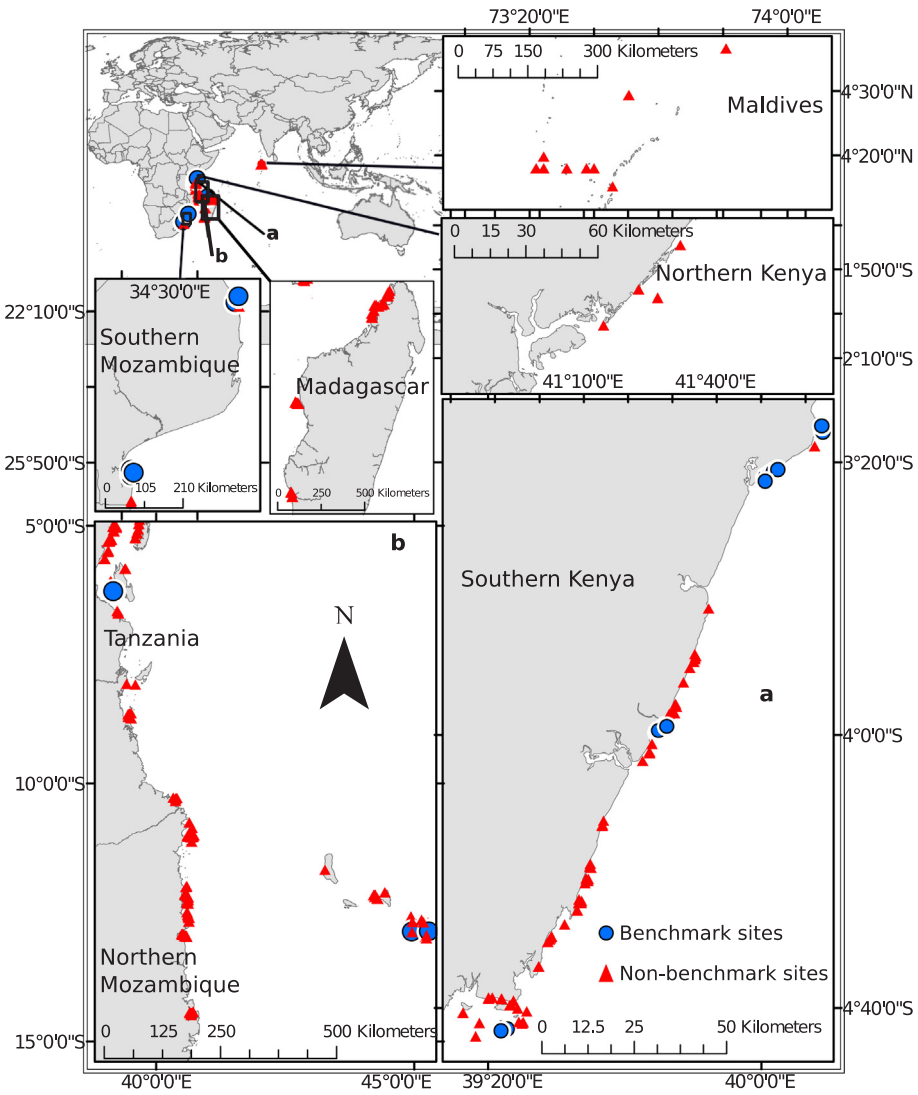

Fig. 1. Map of the western Indian Ocean study region and the location of fished and unfished or benchmarks reef sites.

et al., 2000). Similar principles and methods have been applied to evaluate changing coral reef fish life histories (McClanahan and Humphries, 2012; McClanahan and Graham, 2015). Yet, the usefulness of community life history or traits and how they compare to benchmark or unfished conditions is still poorly studied for marine and coral reef fisheries. It is generally expected that weighted community traits will approach benchmarks asymptotically over time or as a community reaches its maximum biomass and energy consumption (Odum, 1969, 1988). Predictions would be that community length, age, and trophic level should decrease while growth and mortality traits would increase as fishing effort increases and biomass declines (McClanahan and Graham, 2015). However, traits will vary in their sensitivity to changes of fishing effort, biomass, successional time, resource limitations, and other ecological conditions (Tilman, 1990). Consequently, knowing how traits respond and comparing their variation will better assist making evaluations and robust predictions of status (Jennings, 2005). To test these hypotheses, I used 9 common traits as potential indicators of fish community responses along a fishing effort-biomass gradient. The expectation was that as the biomass of the sites increased, single and multivariate community traits should asymptotically approach metrics calculated for unfished benchmark reefs. Thus, comparing single and multivariate responses provides a basis for evaluating the generality and variability in responses and determining the possibility of having global trait metrics for evaluating reef fish status.

2. Materials and methods

The evaluation used biomass data derived from Underwater Visual Census (UVC) of coral reef fish communities in the western Indian Ocean collected by a single observer (McClanahan, 2018a). Data were collected in 449 sites between 2005 and 2016 in reefs over 20° of latitude and longitude and 11 m of depth (Fig. 1). Studied sites included a full range of fishing effort and biomass but also included the oldest and largest fisheries closures in the western Indian Ocean (McClanahan et al., 2015, 2018a). More than 95% of the sites were sampled only once and mostly for two replicate transects or an area of 1000 m^2. A small number of sites had more samples either in time or space and transects were pooled into annual increments and the site/time averages used in the evaluations. The individual censuses were 500 m^2 areas in which individual fish were identified to 23 families and sized into 10 cm intervals. These count and size data were converted into wet weights using family-specific length-weight relationships. Biomass data were further categorized and analyzed in four partially overlapping categories; total unfished biomass, fishable biomass, targeted biomass, and non-targeted biomass. Here, I defined fishable biomass as the biomass of all fish > 10 cm excluding all damselfishes. Targeted biomass was the sum of the following families: Carangidae, Haemulidae, Holocentridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, Serranidae, Siganidae, Sphyraenidae, Carcharhinidae, Ginglymostomatidae > 10 cm