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Fishery characteristics in two districts of coastal Tanzania

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ABSTRACT

Nearshore marine fisheries provide the main source of protein for nearly 9 million people in coastal villages of Tanzania, yet for decades the fisheries have shown signs of overexploitation. These fisheries are small-scale and co-managed by local coastal communities and governmental authorities in groups known as Beach Management Units (BMUs). BMUs record individual fishing trip data (e.g. gear, vessel, taxa); however, the catch data have only been analyzed in nationally aggregated statistics. The objective of this study was to determine if BMU catch-assessment surveys can provide information on the fishing characteristics of small-scale fishing communities in Tanzania. We collected all available landings data from 2014 to 2017 from BMUs in fourteen villages in two spatially, socially, and ecologically distinct districts (Pangani and Rufiji) of the country. Our results show that each village had unique patterns for vessel-use, gear-use, and taxa landed, and that every village was specialized in some measure. Specifically, two villages in Pangani district landed octopus or parrotfish almost exclusively, suggesting potential trophic cascades after years of overexploitation. Furthermore, village fisheries had shared characteristics within their district, thus describing how fishing patterns vary at multiple spatial scales along the coast. Although imperfect, the catch data collected by the community organizations have generated the first descriptions of how village-based fisheries in Tanzania function. Using these findings, we suggest implementing local monitoring data and analysis into the fisheries management plans at the village and district scale. Continuing to collect and analyze community collected data is necessary to gain insights into the range of characteristics of small-scale fisheries to improve current management programs.

1. Introduction

Management of multi-species, multi-gear, small-scale fisheries in tropical latitudes has historically posed significant challenges to scientists and resource managers throughout the globe (Berkes et al., 2001; Mahon, 1997; McClanahan, 2011; Pauly, 1997). These fisheries account for a small proportion of the total global fisheries landings, yet serve as the main protein source and income generating activity for millions of impoverished people living in developing nations (Donner and Potere, 2007; FAO, 2016; Newton et al., 2007). The implementation of traditional fisheries management—which has tended to focus on single species stock assessments—to these small-scale fisheries has proven problematic (Berkes, 2003; Berkes et al., 2001; Cinner et al., 2012). Management measures for small-scale fisheries likely need to account for the socio-economic conditions of fishing communities (McClanahan et al., 2009; Pauly, 1990) while simultaneously developing strategies to collect and analyze data in ecologically complex systems (Matsuda and Abrams, 2006; McClanahan and Mangi, 2004; Pauly et al., 1998).

Small-scale fishers are driven by social, economic, and environmental variability (Kittinger et al., 2013; Leenhardt et al., 2015; Mace, 2014), and management institutions must address the causes of, and potential responses to, their system's variability in order to maintain the capacity to adapt (Finkbeiner, 2015; Folke, 2006; Young et al., 2006). In small-scale fisheries, this adaptation capacity is often reliant on individual fisher behavior. Fisher behaviors are defined by the decisions that fishers make about when, how, and where they will fish, as well as for what species (Hilborn and Walters, 1992a; Kasperski and Holland, 2013; Smith and McKelvey, 1986). These behaviors are often dependent on which fishery (defined by fishing location, gear-use, vessel-use, and target species) they operate in. Furthermore, individual fisher behavior is aligned along a gradient of specialist (operating in one fishery) to generalist behavior (operating in multiple fisheries) (Finkbeiner, 2015; Salas et al., 2004; Smith and Hanna, 1993; Smith and McKelvey, 1986).

Abbreviations: BMU, Beach Management Unit; CPUE, Catch Per Unit Effort

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Specialization generally predominates in systems characterized by low temporal variability in catch, while generalization dominates in systems with high variability in catch. Specialists operate more efficiently in their fishery due to expertise in their use of vessel, gear, and capture of taxon, while generalists are less efficient due to their lack of specific expertise in these areas, but benefit from the ability to switch between fisheries should there be a need (Smith and McKelvey, 1986). Most small-scale fishers are considered generalists because switching between target species is often a common tactic (Salas and Gaertner, 2004). However, managing small-scale fisheries without accounting for local fisher behavior can lead to the formation of systems with limited adaptation capacity.

Marine fisheries in Tanzania are the main source of protein for the coastal communities of nearly 9 million people (Hamidu, 2012), yet these fisheries have shown signs of overexploitation for decades (Berachi, 2003; Hamidu, 2012; Jacquet and Zeller, 2007; Mapunda, 1983). For example, an increase in fishing effort by coastal fishers in Tanzania in the 1980's had little effect on total catch (Mapunda, 1983), while declines in catches of various commercial species, specifically of reef fishes throughout the coast of Tanzania, were recorded nearly 20 years later (Jacquet and Zeller, 2007). Furthermore, landings of coastal species in Tanzania are chronically under-reported (landings are at least 1.7 times higher than reported) and catch rates appear to only be maintained by a continual increase in effort (Jacquet and Zeller, 2007) and gear modification, such as the practice of using mosquito nets to seine for small fishes (Bush et al., 2017). Tanzanian marine fisheries are 99% artisanal (Sobo, 2004) and catches are used mainly for subsistence, with only a few species caught intended for commercial sale (Hamidu, 2012).

The main objective of co-management programs is to share resource management responsibility between the government and stakeholder groups, with the goal of promoting and providing more equitable management and governance (Armitage et al., 2007). Thus in 2003, the Tanzanian government established a community-based co-management program (Beach Management Units—BMUs) for fisheries nationwide (Sobo, 2012). Since the inception of these BMUs, the government, in collaboration with the World Wildlife Fund, has established 204 BMUs along the Tanzanian coast (Kanyange et al., 2014). One of the major purposes of these BMUs is to use local fishers as data enumerators to be responsible for catch-assessment surveys. Catch assessment surveys are used to survey fishery landings throughout the coast (Sobo, 2016). These surveys were designed to estimate total fish production by weight and value, catch per unit effort, and to conduct stock assessments. It is expected that using local fishers at each BMU landing site (i.e. representing villages or within villages) to collect data and return it to centralized (statistics) offices for analysis would allow for more complete coverage of data collection for these fisheries that lack centralized landing ports.

Due to the decentralization of the government and transfer of management duties to local governments in the late 1990's, the local district councils and BMUs themselves are responsible for financing BMUs (Hamidu, 2012; Kanyange et al., 2014). As a result, over 90% of BMUs do not generate enough finances to perform their desired operations, and at least half of them have no strategy to improve this situation. Despite the lack of funds, an apparent dissatisfaction in data recording, and a perceived decline in fisheries landings, the majority of BMUs have been perceived to be useful by local communities, likely due to local conflict resolution and a feeling of involvement (Kanyange et al., 2014). Current datasets collected by the BMUs have only been analyzed using data from a subset of BMUs in aggregated summary statistics (e.g. total number of fishers, total number of gears used, and total value landed). Furthermore, there are many BMU landing sites that are collecting data that are not being represented in the summary statistics. Without an analysis of the collected data at smaller spatial scales (i.e. district or village), these communities may have little reason to continue collecting data as it will not be seen as useful for the management of their fisheries (Cinner et al., 2009).

The objective of the current study was to determine if BMU catch-assessment surveys can provide information on the behavior of small-scale fishing communities in Tanzania. We first identified what forms of catch-assessment survey data were consistently collected among 14 total villages, across two spatially, socially, economically, and ecologically distinct districts of Tanzania over a three-year period. Second, we compared these data to identify similarities and differences between village fisheries. Finally, we discussed the potential social, economic, and ecological factors which may be driving the observed fishery characteristics.

1.1. Study site

This study focused on villages in two distinct coastal districts of Tanzania, henceforth described by their approximate administrative boundaries as Pangani and Rufiji (Note: villages are the smallest spatial scale, they are nested within districts, which are nested within regions in Tanzania). Pangani is a northern district which covers approximately 1800 km^2 and is characterized by an arid climate and many coral reef fringed islands (Samoilys and Kanyange, 2008). It is home to around 55,000 people (TZNBS, 2013), many of whom are highly dependent on fishing for their livelihoods. Pangani is a district within Tanga region. Tanga region has been historically infamous for dynamite fishing, a practice that has demolished a large fraction of the region's coral reefs, and in turn resulted in dramatic reductions in fish abundance (Samoilys and Kanyange, 2008; Turque and Casper, 2016). Rufiji is a southern district defined by its large river delta (the largest in East Africa; Caras, 2001). The Rufiji River Basin covers approximately 177,000 km^2 and contains the largest mangrove wetland (~53,000 ha) in Eastern Africa (Turpie, 2000). Due to the discharge of freshwater, nutrients, and silt there are few coral reefs off of the delta. The Rufiji delta is the most important prawn producing area in Tanzania (Richmond et al., 2002). The population of 220,000 people in Rufiji (TZNBS, 2013) is larger than Pangani (55,000) but is also spread over a larger area, resulting in a lower population density (17 people km^{-2} in Rufiji compared to 31 people km^{-2} in Pangani). The decreased density of the Rufiji population is likely due to the difficulties in developing infrastructure in an area prone to flooding events (Richmond et al., 2002). Similar to Pangani, many of the people in this district are heavily reliant on marine fisheries for their food and livelihoods. The marine fisheries are over-exploited, and almost all fish that are caught appear to be immature or just reaching maturity (Richmond et al., 2002). The over-exploitation may be the result of increasing population size (including many temporary migrants), habitat destruction, and/or the expansion of destructive fishing methods (Richmond et al., 2002).

2. Methods

In 2016 and 2017 we obtained historical BMU catch-assessment survey records. The records in Rufiji district encompassed the period between 2014 and 2016 while the records in Pangani district included data from 2016 to 2017. Villages within districts did not conduct catch-assessment surveys on a regular, continuous basis, and as a result, the dates in which surveys were conducted varied between villages and districts. Due to the lack of continuous records within and between villages, we cannot determine if surveys from certain time periods are absent, or if they were simply not conducted. As the survey records themselves could not be transported out of country, digital copies were made (see Appendix Figure A.1 for an example) and the original records were returned to the BMU officers. Survey records were then translated from Swahili to English using a combination of online language references and discussions with local fishers and BMU officers (including co-author H. Tillya). All translations were maintained and recorded to assist in future analyses (Appendix Table A.1).

BMU catch-assessment surveys were used to collect data from individual fishing trips. The type of vessels used within the fisheries are small, and therefore, the number of fishers per boat (trip) is typically low (1–5 fishers). As a result, the unit of inference for all analyses is based on individual fishing trips, irrespective of the number of fishers involved. All catch-assessment surveys had approximately the same templates (see Appendix Fig. A.1 for an example). Data entry was performed by BMU enumerators and included: *village*, *port*, *BMU enumerator name*, *date*, *fisher village of origin*, *gear* (*type* and *number*), *vessel used*, *vessel registration*, *location of catch*, *departure time*, *return time*, *trip recentness*, *taxa* (*type*, *weight*, *number*, and *value*). Data were recorded inconsistently, although certain data types were less likely to be recorded than others (e.g. *vessel registration*).

Although the fisheries described here are opportunistic, we examined fishery-dependent data, collected without the intent to characterize species diversity. Thus, we used the term “*taxon*” to define each grouping (e.g. Groupers, Prawns, Jacks, etc.) and “*fishery richness*” to describe the number of groupings, to emphasize the inherent folk taxonomic nature of the data (May 2005). Local fishers are able to identify the most commonly landed species (Berkes et al., 2001); however, consistent identification of less common species can be questionable (May 2005). Additionally, certain Swahili words used to identify species were not able to be matched to any taxonomy; in some cases, species were binned into other *taxa* groupings as there was no readily apparent distinction between their definitions. The species most commonly landed differed between districts, but the majority of *taxa* identifications were regarded as accurate. Although the use of local groupings can lead to difficulties in drawing ecological conclusions, these taxonomic groups represent species of economic importance to fishers (Obura et al., 2002).

The *catch location* data, while entered occasionally, referred to a local name for a fishing ground; however, without interviewing fishers to a greater degree we were unable to identify all specific geographic locations. Therefore, location was largely unknown and not included in the analysis. In contrast, catch landed per *village* was included because given the small-scale nature of the fishers and the vessels that they used, the village was likely relatively close to the location of capture. The monetary *value* of each trip was entered either by *weight* or by the total catch per species, depending on the BMU enumerator who recorded the data. We attempted to adjust these *values* accordingly to set all data in the same format based on our knowledge of approximate prices per kilogram of each species. There is still uncertainty in the *value* data entry and any conclusion using this data is tentative until further data are obtained in the future.

The FAO guide to Marine and Brackish Species in Tanzania (Blanchi, 1985) contains information on each species in coastal waters. The information includes average and maximum sizes, fishing gears, and macro-habitats where each species is commonly found. These published data were digitized and compared to our BMU taxa groupings, and used here to examine species-habitat relationships. *Taxa* groupings were explicitly associated to coral reef or estuarine habitats when a larger number of species in each taxa group were reported to use that habitat.

We evaluated the fishery data by single variables first (e.g. *location*, *season*, *vessel*, *gear*, *fishery richness*, *catch biomass*, and *catch*). Then we paired data to determine associated patterns and trends. Because there is not an operational definition for the differentiation between specialist and generalist fisheries, we defined specialization to be when the majority of fishing trips ($>$ 50%) within a village over the study period used a single vessel, gear, or landed a specific taxon. This definition was generated based on a visual examination of the trends in our data. We used descriptive statistics, *t*-tests, ANOVAs, and the Tukey Honest Significant Difference post-hoc test to analyze single variables and their interactions. All analyses were done in R (R Core Team, 2017).

3. Results

3.1. Single-variable analyses

3.1.1. Spatial and seasonal data

There were 720 recorded fishing trips across Pangani district representing 8 villages: Kipumbwi, Mkwajuni, Msaraza, Pangani Mashariki, Pangani Magharibi, Stahabu, Ushongo, and Ushongo Mtoni. Pangani fishing trips occurred between 2016 and 2017. The total number of trips reported for Rufiji district (479) included 6 villages: Jaja, Kiechuru, Mbwera Mashariki, Mbwera Magharibi, Mbwera, and Pombwe, in the period 2014–2016. Because of the limited data in certain villages, we either pooled the data to increase sample size or the villages were excluded from the analysis. Data were limited and therefore excluded from the following villages in Pangani: Mkwajuni, Kipumbwi, Ushongo Mtoni, and Msaraza. While for Rufiji, we excluded Mbwera and Mbwera Magharibi. Pangani Mashariki recorded the largest number of trips in Pangani (n = 207, 28.8%), followed by Ushongo (n = 172, 24%), Pangani Magharibi (n = 164, 22.8%), and Stahabu (n = 125, 17.4%). These villages recorded similar numbers of fishing trips to one another when compared to the villages in Rufiji. In Rufiji, Kiechuru collected the most data by far (n = 330, 68.9%), followed by Pombwe (n = 93, 19.4%) and Mbwera Mashariki (n = 35, 7.3%) (Fig. 1) (Fig. 1).

We observed substantial differences in the data collection schedule between districts and villages within districts. Data were collected during different years, seasons, and months between districts (Fig. 2). There was almost no overlap in the dates of collection between districts. The majority of data in Pangani were collected during the long rain (March through May) and long dry (June through September) seasons, while the majority of data in Rufiji were collected in the long dry and short dry (January through February) seasons. Additionally, data collection showed different patterns in different locations. For example, the majority of data collected in Ushongo were in the long rain season in both 2016 and 2017. Pangani Magharibi fishing trips were evenly split between the long dry and the long rain seasons. Most data were collected in Kiechuru during the long dry season. The variability between months, seasons, and years, both between and within districts precludes the ability to examine temporal trends with any confidence. As a result, additional analyses will generally ignore the effects of time, despite its well documented importance on fisheries catch (Beddington and May 1977; Fulanda et al., 2009; McClanahan, 1988; Winemiller and Jepsen, 1998).

Villages showed different numbers of fishing trips per day. In Pangani district, Pangani Mashariki, Stahabu, and Ushongo recorded one trip per day on most days ($>$ 74%), with a lower frequency of two to six trips recorded per day. Pangani Magharibi recorded two, three, and four trips per day more often (55%) than in the other three villages in Pangani district. The only village in Rufiji to record one trip per day most often was Kiechuru (82%). Jaja and Mbwera Mashariki generally recorded two trips per day (41% and 45% respectively), while Pombwe was relatively split between recording one and two trips per day ($\sim$45% each).

3.1.2. Vessels

Although vessels require registration by law (Sobo, 2004) few were registered ($\sim$6%), especially in the Rufiji district ($\sim$1%). Seven categories of vessels were described in the BMU survey records (Table 1). Vessel type varied by district: canoes were the dominant vessel type (90%) in Rufiji district, while in Pangani district ngalawas (63%) were also used in addition to canoes (18.7%). Although there were six other types of vessels used across the districts, legs was the only other vessel to account for a significant proportion of trips (Rufiji 5.5%; Pangani 8.3%).

Fishers specialized in the use of one vessel in both districts. Various types of vessels were used in the villages in Pangani, although Ngalawas

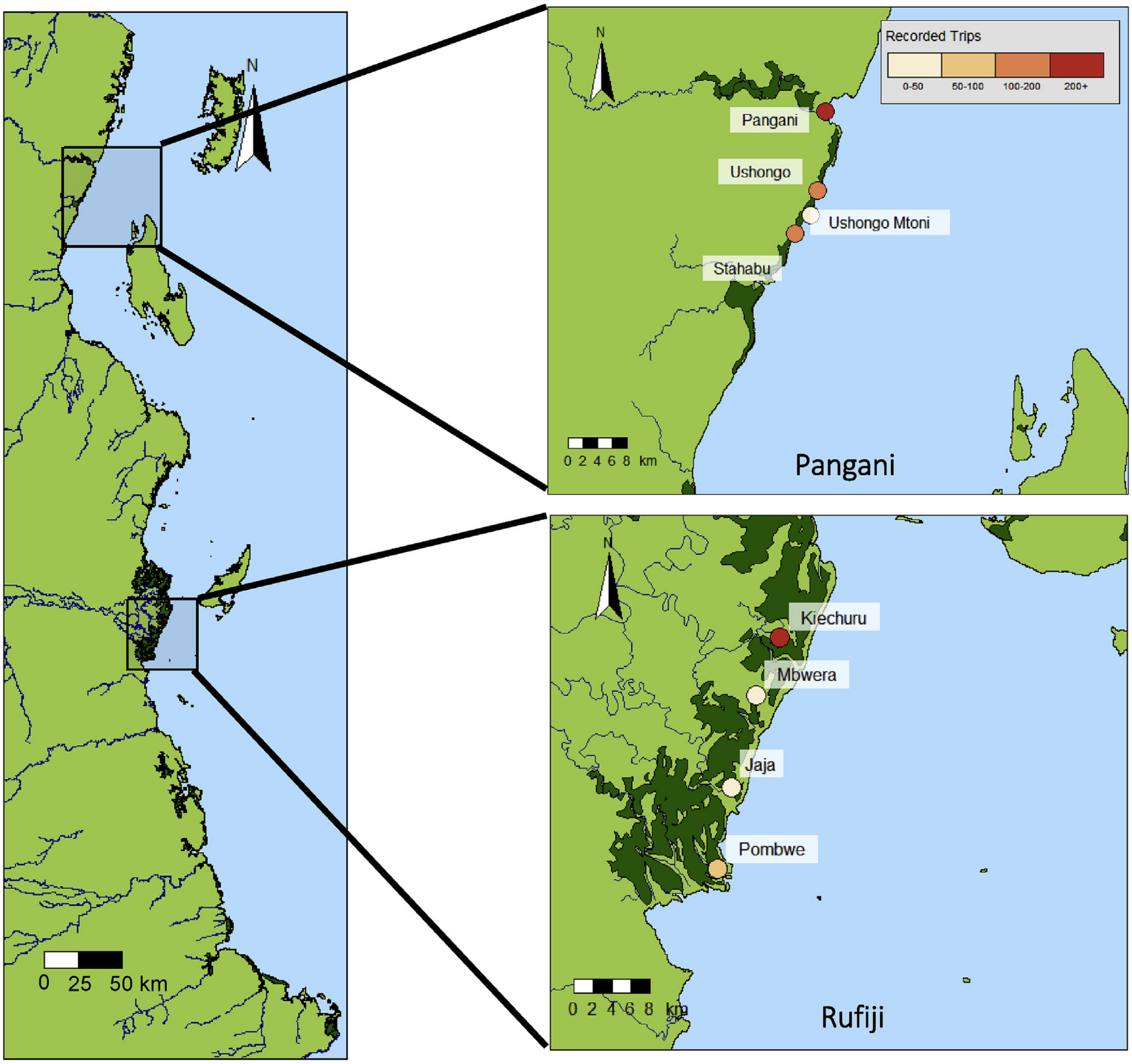

Fig. 1. Map of Tanzanian coastline (left), Pangani District (upper right), and Rufiji District (lower right). Circles define the location of the major villages in each district, with the color of the circle indicating the number of surveys used in this study. Dark green represents mangrove wetlands, while dark blue lines represent relative river position (not scaled to represent river width as that data was not available). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

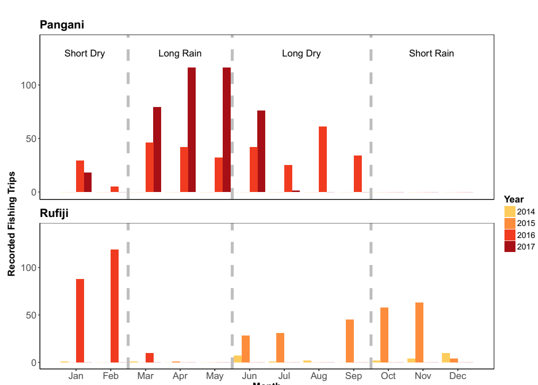

Fig. 2. The recorded fishing trips in the eight villages with the most data in Pangani (top 4 panels) and Rufiji (bottom 4 panels) by month, season, and year.

Table 1
Vessel type and descriptions for all vessels included in the BMU data.

Vessel Type	Description
Boat	Wooden plank boat, powered by engine
Canoe	Hollowed out wooden vessel, powered by paddle
Dhow	Larger wooden boat with angled mast, powered by sail
Legs	No vessel, walked to fishing grounds
Mashua	Wooden plank boat, powered by sail or engine
Ngalawa	Hollowed out wooden vessel with outriggers, powered by sail
Ngwanda	Wooden plank boat, powered by engine (different keel from Boat)

made up the largest proportion of trips in every village except Pangani Magharibi. Pangani Mashariki and Ushongo had the highest number of vessel types (4 and 5 respectively), in contrast to Stahabu village where only ngalawas were used. Pangani Magharibi was the only village in Pangani district where canoes were used instead of ngalawas.

Unlike in Pangani district, fishers in Rufiji relied on canoes in all villages. Although Kiechuru and Pombwe used vessels in addition to canoes, canoes were still used in > 75% of the trips. The next most

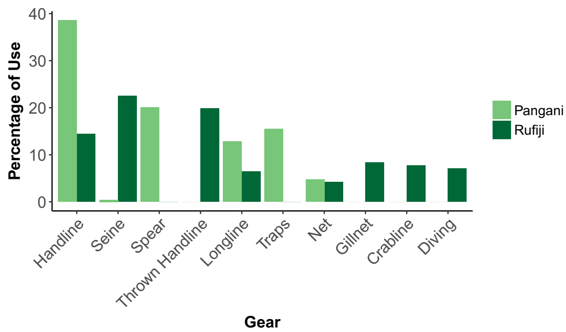

Fig. 3. The percentage of use for the ten most frequently used gear types within Pangani and Rufiji, Tanzania, 2014–2017. The gears that were not included in this figure accounted for 9.4% of trips in Rufiji and 7.8% of trips in Pangani.

common vessel type used was legs. This category included women/children collecting nearshore species or male fishers using nets or spears from the beach.

3.1.3. Fishing gears

There were 16 types of gears included in the BMU survey records (see Appendix Table A.2 for descriptions). The percentage of use varied between district with trips in Rufiji district most frequently using seines, thrown handlines, and handlines (Fig. 3). Fishers in Pangani district mostly used handlines, spears, and traps. Every village in Pangani was specialized in using one gear (Pangani Mashariki and Magharibi: handlines; Stahabu: traps; Ushongo: spears). In Rufiji district, Kiechuru and Pombwe showed a large diversity in gear types (10 and 5 respectively), without specializing in any one gear as was observed in Pangani district. However, Mbwera Mashariki used only nets and handlines, while Jaja specialized with gillnets.

3.1.4. Fishery richness

Fishers reported landing 95 different locally identified (Swahili) fish groups, based on appearance. Because Swahili fish groups are not based on scientific taxonomy, some groups needed to be binned into broad (English) taxonomic groups that resulted in a smaller fishery richness of 61 taxa. The remainder of the analysis will focus on these taxa for ease of interpretation. Pangani district had a greater fisheries richness (50 taxa) than Rufiji district (34 taxa). Within Pangani district, Pangani Mashariki, Pangani Magharibi, and Ushongo fishers landed the greatest number of unique taxa (29, 24, and 20 taxa, respectively). Fishery richness was not directly related to the number of recorded fishing trips, as Pangani Magharibi fishers caught a wider variety of taxa with fewer trips than Ushongo fishers (24 taxa in 164 trips and 20 taxa in 172 trips, respectively). Similarly, Stahabu fishers caught the same number of unique taxa (10) as Ushongo Mtoni fishers yet had far more recorded trips (125 and 17 trips, respectively). In Rufiji district, Kiechuru and Pombwe recorded the same number of taxa (20) despite large differences in the number of recorded fishing trips (330 and 93, respectively). Prawns, groupers, and crabs were the most commonly caught taxa in Rufiji (Fig. 4). In Pangani district, octopus, parrotfish, and crabs were the most common. Thus, both districts focused fishing efforts on invertebrates rather than finfish.

A number of villages specialized in landing specific taxa. For example, Msaraza reported mainly crab catches, Stahabu caught mainly parrotfish, and Ushongo and Ushongo Mtoni caught mainly octopus. Fishing efforts in Pangani Mashariki and Magharibi were generalist but caught mostly finfish taxa. Villages in Rufiji were also generalists and no village specialized in the landing of a specific taxon. Despite this, taxa composition varied between every village in Rufiji.

The primary habitat of landed taxa in Rufiji and Pangani differed (Fig. 5). Rufiji fishers landed estuary-associated taxa (321 times) more often than coral-associated taxa (254 times). Pangani fishers landed coral-associated taxa (700 times) more often than estuary-associated taxa (218 times).

3.1.5. Catch biomass

Villages with the highest number of recorded fishing trips did not always correspond with the largest biomass catch. For instance, Stahabu village had far more recorded trips than Msaraza (152 and 36, respectively) but landed a smaller biomass (1260 kg landed in Stahabu and 1803 kg landed in Msaraza). Similarly, in Rufiji district, Pombwe landed a larger biomass (2151 kg) than Kiechuru (1862 kg), yet there were fewer trips recorded in Pombwe. One clear case representing the decoupling between the number of trips and total catch (biomass) along the Tanzanian coast was the village of Kiechuru, where the total biomass was lower (1862 kg) than in three of the villages in the Pangani district: 4772, 4230, and 3898 kg.

3.1.6. Total catch value

Similar to the biomass catch pattern, the villages with the largest total fish biomass caught did not necessarily correspond to the largest catch value ($1 USD = 2200 TSHs [2017 value]). Pangani Mashariki caught a smaller biomass than both Pangani Magharibi and Ushongo ($\leq$530 kg), yet this biomass accounted for a larger total value ($\geq$$219 USD). Another example of this pattern existed between Kiechuru and Pombwe. While the differences between these villages were relatively small, the change in rank-order of villages based on biomass and value of landings showed that value of catch per kilogram resulted in different yield. Additionally, the number of recorded fishing trips in a village did not correspond to total value landed (Fig. 6). The difference between number of fishing trips, biomass, and value landed describes how trips in certain villages were more valuable (e.g. Pombwe, Pangani Magharibi) than trips in others (e.g. Kiechuru, Pangani Mashariki, Stahabu).

3.1.7. Value per kilogram

An initial analysis using *t*-tests of the value per kilogram data showed non-normally distributed data and heteroscedastic residuals, thus, values above the 95% quantile and below the 5% quantile were removed. Because original BMU surveys were recorded by hand, some numbers were difficult to read and potentially had one too many or too few zeros; removal of these potential outliers based on quantile range allowed for the reduction of bias. Values below the 5% quantile were represented by rays and sharks, which generally had particularly low value per kg, while values above the 95% quantile included crabs and lobsters. Crabs and lobsters are valued differentially based on size. For example, a 2 kg crab is worth more than double a 1 kg crab, likely due to the change in the ratio of meat weight to carapace weight. This variability in the assignment of monetary value contributed to the non-normally distributed data, heteroscedastic residuals, and bias towards locations with larger crabs when examining the relationship between district and villages within district. To account for this bias, invertebrates and finfish were analyzed separately.

The finfish value per kg was higher in Pangani district ($1.50 kg^{-1}) than in Rufiji district ($1.05 kg^{-1}; see Table 2). Only four taxa were more valuable per kilogram in Rufiji than in Pangani: prawns, crabs, variegated emperors, and rays (see Appendix A.3 for value per kg for all taxa). The ANOVA for value per kg also found differences between the villages (Pangani Mashariki, Pangani Magharibi, Stahabu, and Ushongo) within Pangani District (Table 2). All village combinations were different from one another except for Pangani Magharibi and Ushongo (Tukey Honest Significant Differences Post-Hoc). Pangani Mashariki had the highest mean ($\pm -$ standard deviation) value per kg ($1.90 $\pm$ 0.27 kg^{-1}), followed by Pangani Magharibi ($1.55 $\pm$ 0.37 kg^{-1}), Ushongo ($1.43 $\pm$ 0.38 kg^{-1}), and finally Stahabu ($1.21 $\pm$ 0.16 kg^{-1}). A similar comparison between finfish in Rufiji could not be completed because landings within villages almost always had the exact same value per kg, therefore, any variability

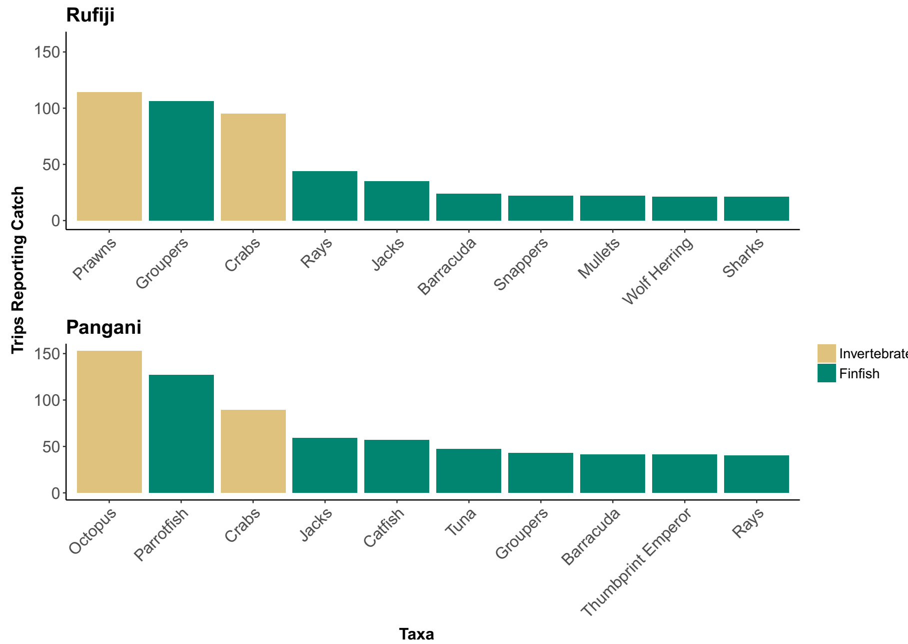

Fig. 4. The ten most commonly caught taxa in Rufiji and Pangani, Tanzania, 2014–2017.

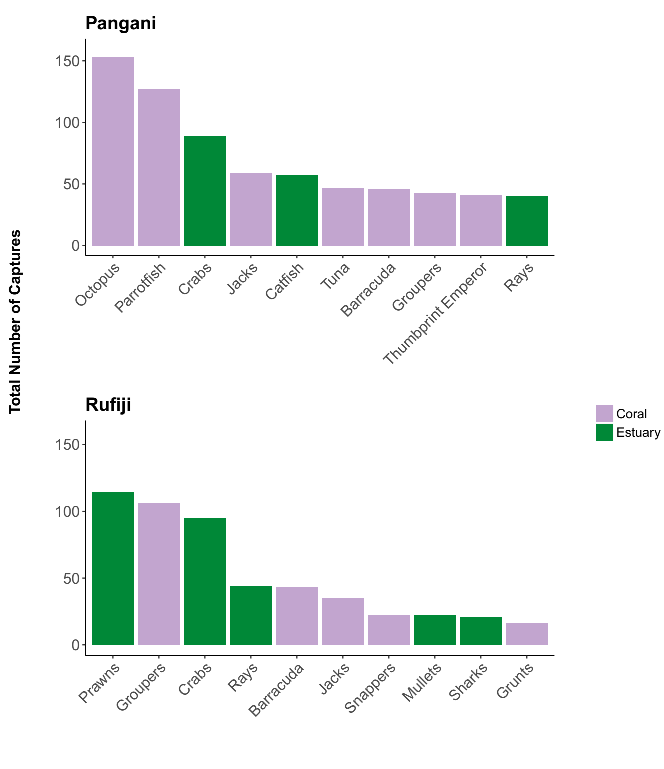

Fig. 5. The total number of trips which landed each of the ten most frequently landed taxa in Rufiji and Pangani, Tanzania 2014–2017.

around that median value lead to residual heteroscedasticity. Due to this characteristic we will describe villages in Rufiji district by their median value per kg rather than with the mean. Kiechuru and Jaja median value per kilogram was \$0.91 kg^{-1}, while in Mbwera Mashariki and Pombwe the median value was \$1.14 kg^{-1}. Only one trip landed prawns in Pangani district (Pangani Magharibi), so comparisons between districts and within Pangani district were not possible. In the case of Rufiji district, only Kiechuru and Pombwe landed prawns on multiple trips and similar to the finfish landings, the prawn value was the exact same value on almost every trip within village (Kiechuru = \$2.27 kg^{-1}; Pombwe = \$1.15 kg^{-1}).

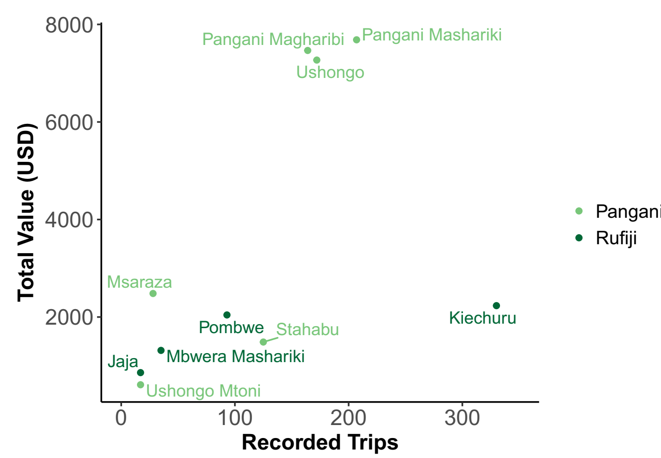

Fig. 6. The total value of landings by the number of recorded fishing trips in each village within Pangani and Rufiji, Tanzania, 2014–2017.

3.2. Multivariable comparisons

3.2.1. Vessels and taxa

Using the ngalawa, the most common vessel in Pangani, fishers landed 37 different taxa. The majority of trips landed finfish, except in Ushongo where octopus was the most common taxon (44% of trips). The highest proportion of trips using ngalawas in Pangani Mashariki landed emperors (28.5%) and tunas (18%), in Pangani Magharibi jacks (19.6%), and Stahabu mainly caught parrotfish (79%). Ngalawa-based landings in Pangani Mashariki and Magharibi were not dominated by any one particular taxon like in Stahabu or Ushongo.

Canoe use in Pangani Magharibi landed 19 taxa, and included crabs (28.8%) and catfish (24.7%). "Legs" fishers in Pangani Magharibi landed 9 taxa and most of the catch was crabs (42.9%). When using legs or ngwandas, fishers in Ushongo landed few taxa (5 and 3, respectively) and landed octopus on their trips more often than any other taxon

Table 2
Model equations, test statistics, and *p*-values for all *t*-tests and ANOVAs used throughout the results. Subscripts for *t* and *F* statistics represent the degrees of freedom. Significant *p*-values are shown in bold typeface.

Subsection	Model Type	Response	Predictor	Test Statistic	*p*-value
3.1.7	*t*-test	Finfish value per kg	District	$t_{919.19} = -27.311$	**< 0.001**
3.1.7	ANOVA	Finfish value per kg	Pangani Villages	$F_{4,643} = 4343$	**< 0.001**
3.2.3	*t*-test	log (CPUE)	District	$t_{768.37} = -10.9$	**< 0.001**
3.2.3	ANOVA	log (CPUE)	Pangani Villages	$F_{4,604} = 699.8$	**< 0.001**
3.2.3	ANOVA	log (CPUE)	Rufiji Villages	$F_{4,451} = 200.1$	**< 0.001**
3.2.4	*t*-test	log (Shark Weight)	District	$t_{35.37} = -2.92$	**0.006**
3.2.4	*t*-test	log (Ray Weight)	District	$t_{78.45} = 3.94$	**< 0.001**
3.2.4	*t*-test	log (Grunt Weight)	District	$t_{30.46} = 4.10$	**< 0.001**
3.2.4	*t*-test	log (Jack Weight)	District	$t_{71.46} = 5.46$	**< 0.001**
3.2.4	*t*-test	log (Grouper Weight)	District	$t_{45.99} = 0.36$	0.717
3.2.4	*t*-test	log (Big Barracuda Weight)	District	$t_{47.47} = 1.21$	0.231

(82.1% and 94.1% of trips respectively). Pangani Mashariki and Stahabu villages used ngalawas on most trips, thus landings with other vessels may simply be a function of few reported trips.

Canoe use in Rufiji landed the largest taxa richness of any vessel regardless of village origin. The highest proportion of trips in canoes in Kiechuru landed prawns (28.2%), crabs (22.9%), and groupers (20%). While in Mbwera Mashariki wolf herring (24%), in Pombwe mullets (23.2%), grunts (16.8%), and groupers (20%), and in Jaja rays (32.1%), crabs (21.4%), and queenfish (14.3%) were the dominant taxa. When fishers in Kiechuru used a dhow, their trips only landed 7 taxa, with jacks (28.6%) and sharks (28.6%) caught most often. While on legs they landed 4 unique taxa with most trips catching crabs (60%). The Pombwe village fishers who used boats landed 5 taxa, where rays were common (38.5% of trips), while on legs they only landed *Acetes* sp. Fishers in Mbwera Mashariki and Jaja only used canoes.

3.2.2. Gear type and taxa composition

The most common gears in Pangani district villages landed a variety of taxa. Handlines used in both Pangani Mashariki and Pangani Magharibi caught different taxa (25 and 19 taxa, respectively), although in Pangani Mashariki the most common landings were tunas (18.4% of trips) and emperors (15.2%), while Pangani Magharibi landed mostly jacks (18.2%) and crabs (17.2%). The use of spears in Ushongo landed 10 taxa, although the dominant taxa was octopus (90.7%), while traps in the Stahabu village landed 9 taxa with parrotfish caught most often (86.5%). Longlines in Pangani Magharibi caught mainly the same species as handlines, although catfish was more common (9.6%–30.8%). Ringnets in Pangani Mashariki caught 4 taxa, where landings were mostly sardines (76.9%). Shark nets in Ushongo generally landed rays (47.7% of trips) and sharks (16.7%).

Nets and handlines in Mbwera Mashariki landed nearly the same taxa composition (e.g. wolf herring, rays, jacks, and groupers). Divers in Pombwe landed 6 unique taxa; the most common were mullets (55%), grunts (20%), and groupers (20%). When handlines were used in Pombwe, the second most common gear, landings included grunts (19.5%), groupers (17.1%), and variegated emperors (14.6%). Handlines in Kiechuru village caught groupers (64.3%) more frequently than any other taxa, while seines only landed 3 taxa, with most trips landing prawns (96.6%). Longlines used in Kiechuru caught 14 taxa, with groupers caught most often (25.9%), followed by other pelagic and reef associated species, including the critically endangered and extremely rare coelacanth (5.2% of trips). Finally, gillnets in Jaja caught 9 taxa, landing rays and queenfish most often (41.2% and 23.5% of trips respectively).

3.2.3. Catch per unit effort

Catch per unit effort (CPUE) was defined as the weight landed per trip per fisher. Median CPUE was lower in Rufiji (2.5 kg trip^{-1}) than in Pangani (6.5 kg trip^{-1}). The CPUE data between districts was not normally distributed. Removing data above (95%) and below (5%) quantiles did not contribute to data normalization as performed in the case of the value per kilogram analysis. Thus, CPUE values were logarithmically transformed and compared between districts. When CPUE between districts was compared using a *t*-test, a significant difference was identified, with higher CPUE in Pangani than Rufiji (Table 2).

Differences in CPUE were present even when examined at the village level within each district. In Pangani district, Pangani Magharibi had the highest median CPUE (9 kg trip^{-1}), followed by Stahabu (8 kg trip^{-1}), Ushongo (6.25 kg trip^{-1}), and Pangani Mashariki (3.75 kg trip^{-1}). Median CPUE between villages in Rufiji was similar. Jaja showed the highest median CPUE (12.5 kg trip^{-1}), followed by Pombwe (11.3 kg trip^{-1}), Mbwera Mashariki (11 kg trip^{-1}). Kiechuru CPUE was lower than in other villages in Rufiji (1.5 kg trip^{-1}).

Similar to the *t*-test results comparing district differences, the CPUE results within district had heteroscedastic residuals that were dealt with by log-transformation. All villages in the Pangani and the Rufiji districts were significantly different from the other villages within their respective districts (Table 2). All village combinations but Pangani Magharibi and Stahabu in Pangani district were significantly different from one another (Bonferroni adjusted *p*-values < 0.05). In Rufiji, Kiechuru had a different CPUE than the three other villages (Bonferroni adjusted *p*-values < 0.05), while all other village comparisons were not significantly different.

3.2.4. Taxon weight

There were significant differences in mean weight for some taxa when compared between Pangani and Rufiji districts (Table 2). Because individual fish weight is not provided in BMU surveys, we divided the total weight by the number of fish landed per taxon and report this value as the average fish weight by taxon. Our analysis examined district weight differences for each taxon landed on at least 20 trips in both districts; the data were log-transformed for analysis, although actual mean values are described below. Sharks, rays, grunts, and jacks showed significant weight differences between districts (Table 2). While the species landed in each taxa group may have differed between districts, sharks were 8.4 kg heavier in Rufiji, rays were 4.4 kg heavier in Pangani, grunts were 3.8 kg heavier in Pangani, and jacks were 2.9 kg heavier in Pangani.

4. Discussion

4.1. Fisher behavior

This study sought to determine if BMU catch-assessment surveys can provide an understanding of the behavior of small-scale fishing communities in two distinct coastal districts in Tanzania. Village BMU volunteers recorded fishing trips during different time periods, and the village fisheries differed in their diversity of vessels, gears, and taxa landed during those trips. The selected villages ranged from generalist to specialist in vessel-use, gear-use, and taxa landed, but every village was specialized in some measure. Fishery specialization was operationally defined as the use of specific equipment or landing of a specific taxon on at least 50% of recorded fishing trips in a village fishery throughout the study period. The most obvious examples of specialization were observed in two of the villages studied, Ushongo and Stahabu, in the more densely populated Pangani district, in which fishers specialized in vessel-use, gear-use, and taxon landed.

The specialization of both the Ushongo fishery on octopus and the Stahabu fishery on parrotfish were potentially the result of trophic cascades. It has been well documented that fish communities shift towards low trophic levels in response to predation release in overfished environments (Campbell and Pardede, 2006; Clua and Legendre, 2008; Jennings and Polunin, 1996b; Pauly et al., 1998). For instance, overfishing on Kenyan reefs first resulted in declines in carnivorous fishes that were replaced by octopus, and when both were removed, reefs became dominated by herbivorous fishes (e.g. parrotfish) (McClanahan et al., 2008). It appears that Ushongo reefs, which are dominated by octopus, may be at an earlier stage of the trophic cascade when compared with the parrotfish dominated Stahabu reefs, however, since our results are based on fisheries dependent data, these observations are speculative. This shift towards parrotfish dominance is often accompanied by an increase in coral reef bio-erosion and potential shift to algal dominance (Campbell and Pardede, 2006; Jennings and Polunin, 1996a). It is clear that trophic cascades play a negative role in coral reef health and fisheries landings and further studies should examine whether trophic cascades are truly affecting the reefs studied here.

Village fisheries, like Ushongo and Stahabu, had distinct gear-use and vessel-use patterns that helped define their respective fishers' behavior. Village fisheries had similar behavior patterns within district. For instance, fishers in Pangani district were more specialized and used vessels able to travel farther offshore (e.g. ngalawas and dhows) with a limited number of gears and generally caught larger, reef associated fishes (e.g. emperors, tunas, and jacks). Fishers in Rufiji were more generalized and used vessels which were limited to inshore habitats (e.g. canoes and legs) with a wide range of gears to catch smaller, estuarine associated taxa (e.g. prawns, crabs, and wolf herring). Although gear and vessel-use, as well as taxa-captured, were unique to villages, the similarities within districts describes the importance of the scale of inference for the analysis of these coastal fisheries.

Despite Pangani district fishers showing significant specialization, they landed a larger fishery richness than the generalist fishers in Rufiji. While there are many factors which influence fisheries biodiversity (Connolly et al., 2017; Rochet et al., 2011) one of the major factors driving the differences seen here is likely the environmental setting (i.e. habitat). Coral reefs, which were more commonly accessible in Pangani, generally have higher fish diversity than estuaries (Dorenbosch et al., 2005; Nagelkerken and Faunce, 2008; Unsworth et al., 2007). The difference in habitat-based fish diversity along the Tanzanian coast likely causes some of the difference in the diversity of landed taxa between districts. Furthermore, while it is common for reef fishes to use estuaries as nurseries (Beck et al., 2001; Gajdzik et al., 2014; Kimirei, 2012; Kimirei et al., 2013) juvenile reef-associated fishes inhabiting estuaries would be small and therefore of less interest for the fishery. Additionally, smaller individuals may be more difficult for fishers to identify than reef-associated adults which could lead to fishers grouping species that are captured in estuaries when they would be uniquely identified at larger sizes.

The ability to travel offshore to reefs and pelagic habitats requires an investment in vessels capable of traveling long distances (e.g. motor boats, dhows, and ngalawas), these investments are often made by "middlemen" who hire poorer or less experienced fishers, or provide loans to purchase or rent vessels and/or gears (Fulanda et al., 2009; Richmond et al., 2002; Wanyonyi et al., 2016b). These middlemen may themselves drive the specialization or generalization of fisheries if they impose specific decisions (i.e. for vessel or gear-use) on a majority of fishers who would be unable to fish without loaned equipment (Crona and Bodin, 2010).

Local infrastructure and the transport of resources can also influence fishing behavior. For example, Rufiji has a larger subsistence fishery partially due to the limited infrastructure, which influences price, as middlemen must be paid for export to distant markets (Richmond et al., 2002; Turpie, 2000). In Rufiji, only prawns, crabs, variegated emperors, and rays were of more value per kilogram than in Pangani. This likely drives the generalist behavior that was observed, as fishers will use any resources that they have available to catch any taxa that may feed their communities (McClanahan et al., 2009). In contrast, specialization was observed in Pangani, where increased access to roads and refrigeration (PDC, 2017) provide fishers greater access to vessels, gear, and markets that offer higher prices for targeted fisheries. Furthermore, the ability of communities in Rufiji to import resources may be particularly diminished during the rainy season when roads are flooded, thereby further increasing the reliance on fisheries for subsistence (Richmond et al., 2002).

Seasonality plays a role in marine fisheries (Dilasser, 2009; McClanahan, 1988; Winemiller and Jepsen, 1998); however, due to the lack of overlap in the fishing trip dates of collection between districts we cannot make any direct inferences on this effect. The monsoon brings about wind velocity and rain patterns that makes travel offshore difficult (Crona et al., 2010; Wanyonyi et al., 2016b). For instance, the octopus fishery in Ushongo and parrotfish fishery in Stahabu, both in Pangani district, are known to be seasonal. They supposedly cannot be fished in the Short and Long Wet seasons due to the effects of increased wind and water turbidity on the divers and trap sets (H. Tillya, personal communication). However, due to the lack of balanced temporal data we cannot confirm nor refute this claim. In addition to seasonal trends in wind and turbidity, increased freshwater flow in the Rufiji Delta can lead to finfishes being more available for capture (Richmond et al., 2002). Finally, this seasonal variability may also play a role in the difference in fishing effort and landings between the two districts.

4.2. Fisheries management

The villages examined in this study are not included in the subsample of 32 (out of 204) village BMUs used for calculating aggregated national statistics (Sobo, 2016). Current statistical analysis of these villages aggregates the data by vessel, gear, taxa, biomass, and value of trips to describe nationwide fisheries trends. Yet, there are differences in each metric (time, vessel, gear, taxa, and value) by district and by village within district, specifically when comparing specialist and generalist village fisheries. The aggregated values describe fisheries at the national spatial scale alone and provide the impression of all fisheries being generalist. This form of subsampling and aggregating data from local institutions has been described as having questionable value because it will inherently miss and average local social, economic, and ecological variability (Dietz et al., 2003), and our study provides further evidence of this. Without accounting for regional and local scale analysis of fishery metrics, national statistics will not improve local or regional management strategies and may lead to incorrect conclusions about these small-scale fisheries, especially when such generalizations are drawn from a small, unrepresentative subsample.

Scientifically-based and quantitatively-driven management in Tanzania is, for the time being, unlikely, yet much of the goal of BMU data collection is to allow just that (McClanahan et al., 2009). BMUs catch assessment surveys were created with the goal of conducting stock assessments (Sobo, 2016). One metric that is commonly used in stock assessments for evaluating fish abundance is catch per unit effort (CPUE) (Harley et al., 2001; Hilborn and Walters, 1992b). Despite the well-known issues with CPUE as a sole indicator of fish abundance (specifically over broad geographic scales and for mixed communities) it is a relatively simple first step that can be used for assessing populations (Harley et al., 2001; Maunder et al., 2006). Here, the fishers in the district which maintained a larger human population density and higher fishing pressure, Pangani, yielded a higher CPUE than fishers in Rufiji. This difference presumably describes a higher abundance of fish in Pangani than in Rufiji, which may be the result of specialization and/or habitat context. However, these values of CPUE will undoubtedly vary based on gear, vessel, crew size, time of year, and other factors. A more equal representation of each of these factors (especially season) would be required for meaningful conclusions to be drawn, and as a result, is not possible with the current data.

A second potential use for BMU data may be to monitor the average size of species landed over time or space to identify potential signs of overfishing (Froese, 2004; Graham et al., 2005; Rochet and Verena, 2003). There were six taxa in our study with enough weight data collected in both Pangani and Rufiji to allow a district comparison. There was a significant difference in mean weight of four taxa (sharks, rays, grunts, and jacks) between districts. This difference in size may simply be the result of a difference in the species that make up the taxa between districts, that the fish in different districts have different size at age (growth), or that unobserved gear differences result in size selectivity (McClanahan and Mangi, 2004). For example, if fishes between districts have the same size at age, but are captured at different ages, we would likely identify a difference in the size of landed taxa. However, these differences may also be driven by fishing pressure.

Sharks were larger in Rufiji, which may be the result of more intense, directed fishing pressure in Pangani (Marshall and Barnes, 1997) having captured the majority of old, large sharks. The intrinsic difficulty involved with exporting fish from Rufiji likely limits any form of targeted fishing for sharks (Richmond et al., 2002). Jacks and grunts were larger in Pangani, which may be the result of capture of adults on coral reefs rather than juveniles in nursery habitat (Nagelkerken et al., 2002; Smith and Parrish, 2002). This size difference may also describe healthier than expected reefs, as serially overfished reefs would presumably have reduced numbers of large, high trophic level species. However, as previously mentioned, these differences in size could be the result of various processes and could be false signals altogether. Similar to CPUE analysis, any effort to describe size differences within a taxon would require higher spatio-temporal resolution data collection to justify the creation of management measures. Finally, weights were examined here rather than lengths (the more common size metric; Froese, 2004; Graham et al., 2005) as length was not recorded in catch-assessment surveys. If length could be recorded in addition to what is already recorded, assessments of length frequency may function as a potential indicator of species population/fish community health.

BMU catch assessment surveys have provided a glimpse into the behavior of fishers and the composition of their catch along coastal Tanzania. While the data collected are lacking in various respects, adapting to the limitations of community-based data collection will allow for the implementation of appropriate and achievable fisheries management (McClanahan, 2011). Working with BMU officers to support data collection on a more regular basis, along with a modification of the surveys to include information on fish length and information on whether or not the fish will be used for subsistence or for export, will greatly improve our understanding of the fishery. However, for any of the data collection to be valuable, a system where collected data can be analyzed at regional and/or local scales is necessary. While nationwide analysis can produce overarching shifts in regulations (e.g. banning seines and dynamite fishing) that can create positive change, there are many smaller changes that can be made at the region, district, and village level if fishing behaviors can be identified. Local people want to manage their own resources, and working with them to develop a system where their hard work can benefit their communities should be the ultimate goal.

4.3. Limitations

The village fishery specialization noted in this study may simply be an artifact of data-collection procedures. Data collection by BMU officers may result in over-representation of fishers who are more common, friendlier with the officer, or who fish near where the officer collects data. Information gathered through interviews with fishers have been described as unreliable in other systems (Lunn and Dearden, 2006) and as a result, the conclusions drawn here should be accepted with caution. Additionally, it is possible that defined data-collection procedures are not always followed exactly. While BMU protocol states that BMU officers need to collect data from at least three fishing trips per day (H. Tillya, personal communication), we noted variability in number of trips recorded per day, with many surveys recording fewer than three trips per day. The variability in number of daily recorded trips may be the result of limited BMU funding, the number of BMU officers collecting data, or the local belief in the efficacy of collecting data.

Migrant fishers, both from Tanzania and neighboring countries, are known to follow the monsoon for fishing (Fulanda et al., 2009; Wanyonyi et al., 2016a, 2016b), which may greatly affect seasonal fishing pressure in villages generally used by migrant fishers. In other African fisheries, it has been noted that migrant fishers can make up the majority of fishers (Fulanda et al., 2009; Njock and Westlund, 2010). Migrant fishers differ in their use of vessels and gears from local fishers and may drive a more diverse or specialized fishery than locals as well (Crona et al., 2010; Fulanda et al., 2009; Wanyonyi et al., 2016a, 2016b). Despite the potential influence of migrants on these small-scale fisheries, the BMU data alone does not provide information on which communities are influenced or even if migrants' trips are recorded by BMU data enumerators. Understanding how these migrations influence fishery statistics is important, and should be accounted for in subsequent data collection.

5. Conclusions

Our results describe regional and local variation in the fishing behaviors of coastal Tanzanian communities. While we cannot reveal the ratio of specialist to generalist individual fishers within the fisheries, we do describe community fisheries where most fishers are specialists. The observed generalist and specialist fishing behaviors are driven by the taxa landed, vessel-use, gear-use, population size, infrastructure, season, and local habitats which define the fishing communities. Furthermore, the complete specializations recorded in the Ushongo and Stahabu villages in Pangani district may be the result of trophic cascades and could therefore be ecologically forced rather than chosen strategically by the fishers. Understanding the drivers of local fisher behavior and how these behaviors affect the fishery as a whole is important for managing community economies and local environments over time.

The BMU data examined here have allowed for the first insight into the minutiae of these small-scale fisheries. This study demonstrates that aggregating data on fisheries throughout the coast of Tanzania results in a mischaracterization of the local fishing behavior and as a result, a potential mischaracterization of the necessary management processes needed to allow continued subsistence. Furthermore, our results may indicate ecological trends (e.g. trophic cascades) that have occurred in response to years of overexploitation. Future studies are required to understand the processes behind these trends and how they may be reversed. While community collected data are far from perfect, they have and may continue to allow, for a greater understanding of small-scale fisheries.

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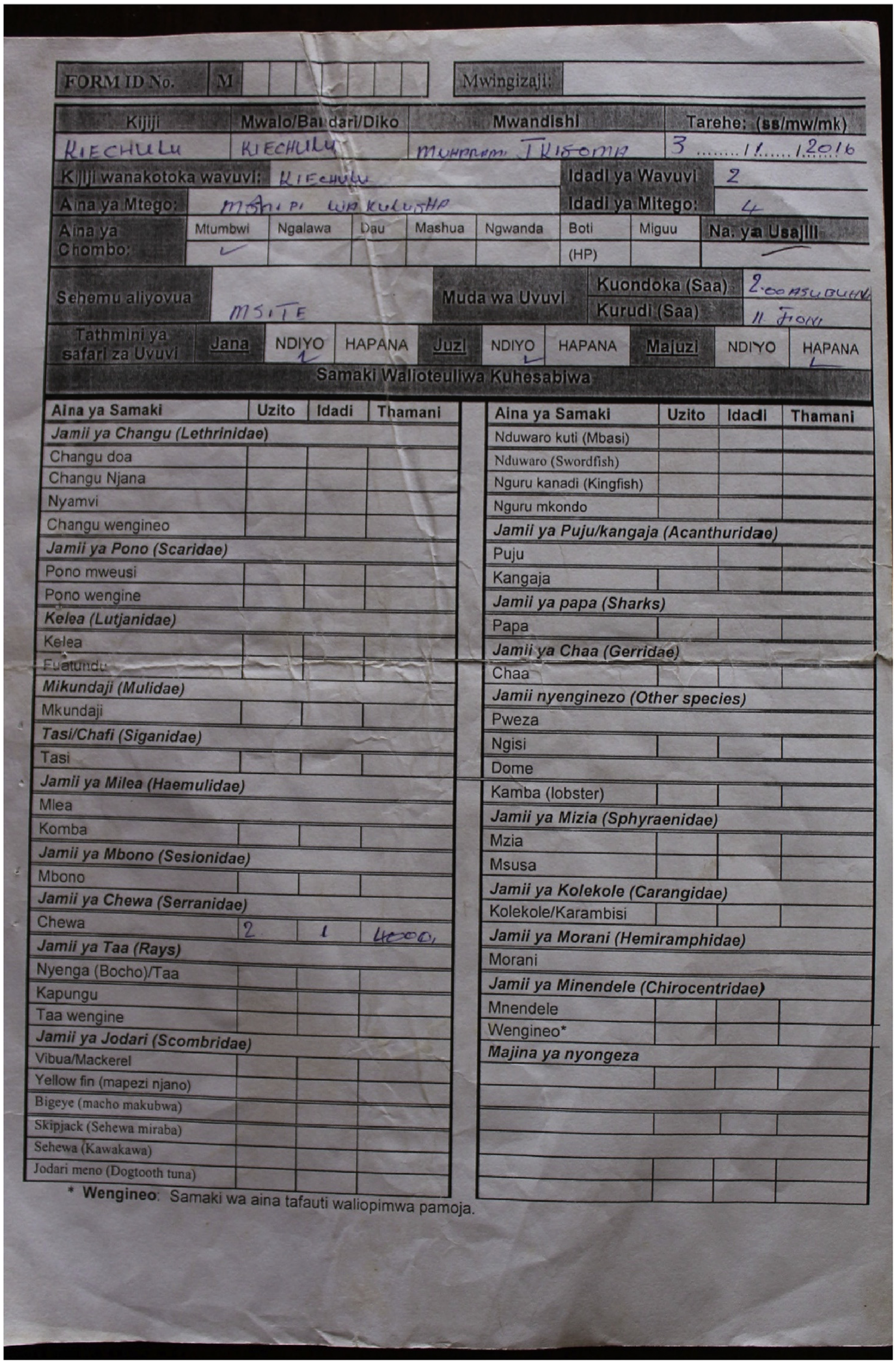
Appendix A



FORM ID No. M | Mwingizaji:

Kijiji	Mwalo/Bandari/Diko	Mwandishi	Tarehe: (ss/mw/mk)
KIECHULU	KIECHULU	MUHARAM J KISOMA	3 ...11... 2016

Kijiji wanakotoka wavuvi: KIECHULU | Idadi ya Wavuvi: 2

Aina ya Mtego: MSHIPI WA KULUSHA | Idadi ya Mitego: 4

Aina ya Chombo:	Mtumbwi	Ngalawa	Dau	Mashua	Ngwanda	Boti (HP)	Miguu	Na. ya Usajili
	✓							—

Sehemu aliyovua: MSITE | Muda wa Uvuvi: Kuondoka (Saa) 2.00 ASUBUHI; Kurudi (Saa) 11 JIONI

Tathmini ya safari za Uvuvi: Jana NDIYO HAPANA | Juzi NDIYO HAPANA | Majuzi NDIYO HAPANA

Samaki Walioteuliwa Kuhesabiwa

Aina ya Samaki	Uzito	Idadi	Thamani
Jamii ya Changu (Lethrinidae)			
Changu doa			
Changu Njana			
Nyamvi			
Changu wengineo			
Jamii ya Pono (Scaridae)			
Pono mweusi			
Pono wengine			
Kelea (Lutjanidae)			
Kelea			
Fuatundu			
Mikundaji (Mulidae)			
Mkundaji			
Tasi/Chafi (Siganidae)			
Tasi			
Jamii ya Milea (Haemulidae)			
Mlea			
Komba			
Jamii ya Mbono (Sesionidae)			
Mbono			
Jamii ya Chewa (Serranidae)			
Chewa	2	1	4000
Jamii ya Taa (Rays)			
Nyenga (Bocho)/Taa			
Kapungu			
Taa wengine			
Jamii ya Jodari (Scombridae)			
Vibua/Mackerel			
Yellow fin (mapezi njano)			
Bigeye (macho makubwa)			
Skipjack (Sehewa miraba)			
Sehewa (Kawakawa)			
Jodari meno (Dogtooth tuna)			

Aina ya Samaki	Uzito	Idadi	Thamani
Nduwaro kuti (Mbasi)			
Nduwaro (Swordfish)			
Nguru kanadi (Kingfish)			
Nguru mkondo			
Jamii ya Puju/kangaja (Acanthuridae)			
Puju			
Kangaja			
Jamii ya papa (Sharks)			
Papa			
Jamii ya Chaa (Gerridae)			
Chaa			
Jamii nyenginezo (Other species)			
Pweza			
Ngisi			
Dome			
Kamba (lobster)			
Jamii ya Mizia (Sphyraenidae)			
Mzia			
Msusa			
Jamii ya Kolekole (Carangidae)			
Kolekole/Karambisi			
Jamii ya Morani (Hemiramphidae)			
Morani			
Jamii ya Minendele (Chirocentridae)			
Mnendele			
Wengineo*			
Majina ya nyongeza			

* **Wengineo**: Samaki wa aina tafauti waliopimwa pamoja.

Fig. A.1. An example of a BMU survey template from Rufiji District.

Table A.1
Swahili to English translations of all words encountered in BMU surveys.

Description	Swahili	English
Gear	2 × 2	2 × 2 inch mesh net/trap
Gear	Dmangu	Spear

(continued on next page)

Table A.1 (*continued*)

Description	Swahili	English
Gear	GN2″	2 inch mesh gillnet
Gear	HL Ndoano	Handline
Gear	Jarife	Gillnet
Gear	Kaputi	Longline
Gear	Kuchimba	Dig
Gear	Kuchokoa	Hand Collecting
Gear	Kutanda	Seine
Gear	Kuzumia	Diving
Gear	Mangu	Spear
Gear	Mchokoo	Spear
Gear	Mshipi	Handline
Gear	Mshipi Kaputi	Longline
Gear	Mshipi wa kaa	Crabline
Gear	Mshipi wa kurusha	Thrown Handline
Gear	Mtando	Ringnet
Gear	Nchi 4 play 9	4 inch mesh net
Gear	Nyavu	Net
Gear	Nyavu chuchunge	Halfbeak net
Gear	Nyavu ya kukokota	Seine
Gear	Nyavu ya kutanda	Prawn Beach Seine
Gear	SH	Shark Net
Gear	Sinia Jarife	Shark Net
Gear	Traps	Madema
Gear	Umangu	Spear
Gear	Zurumati	Longline
Gear	Zurumati Mshipi	Handline and longline
General	Aina ya chombo	Type of vessel
General	Aina ya mitego	Type of traps
General	Aina ya samaki	Kind of fish
General	Asubuhi	Morning
General	Bandari	Port/Harbor
General	Idadi	Number
General	Idadi ya mitego	Number of traps
General	Idadi ya wavuvi	Number of fishermen
General	Jana	Yesterday
General	Jioni	Evening
General	Juzi	The day before yesterday
General	Kijiji	Village
General	Kijiji wanakotoka wavuvi	Fisherman village of origin
General	Kuondoka	Leave
General	Kurudi	Return
General	Majuzi	Recently
General	Mchana	Afternoon
General	Mitoni	Rivers
General	Muda wa uvuvi	Duration of fishing
General	Mwandishi	Writer/Author
General	Na ya usijili	Registration
General	Sehemu aliyovua	Fishing Ground
General	Tarehe	Date
General	Tathmini ya safari uvuvi	Fishing Trip Evaluation
General	Thamani	Value
General	Usiku	Night
General	Uzito	Weight
General	Wengineo	Others
Taxa	Bangra	Yellowtail scad
Taxa	Chaa	Gerridae
Taxa	Changu Doa	Thumbprint emperor
Taxa	Changu njana	Yellow banded emperor
Taxa	Changu wengineo	Lethrinidae
Taxa	Chazanda	Black Lutjanidae
Taxa	Chewa	Serranidae

(*continued on next page*)

Table A.1 (*continued*)

Description	Swahili	English
Taxa	Chuchunge	Hemiramphidae
Taxa	Dagaa	Sardines
Taxa	Dagaa Mchele	Commerson's anchovy
Taxa	Dagaa Saradi	*Sardinella neglecta*
Taxa	Dimbwara	Red Snapper
Taxa	Dome	Cuttlefish
Taxa	Fuatundu	Humphead/Emperor Red Snapper
Taxa	Fulusi	Mahi mahi
Taxa	Hongwe	Catfish
Taxa	Jodari	Scombridae
Taxa	Jodari	Tuna
Taxa	Kaa	Crabs
Taxa	Kamba	Lobster
Taxa	Kamba	Prawns
Taxa	Kamba Dura	Hairy River Prawn
Taxa	Kambamiti	Tiger Prawn
Taxa	Kanda	Chirocentridae
Taxa	Kangaja	Acanthuridae
Taxa	Kapungu	Rays
Taxa	Karamamba	Haemulidae
Taxa	Kelea	Bluestripe/Blackspot Snapper
Taxa	Kipepeo	Platacidae
Taxa	Kisukuku	Coelacanth
Taxa	Koana	Squirrelfish
Taxa	Kolekole	Carangidae
Taxa	Kungu	Lutjanidae
Taxa	Mahongwe	Catfish
Taxa	Mbarata	Shad
Taxa	Mbasi	Swordfish
Taxa	Mbiliwili	Platycephalidae
Taxa	Mishe	*Tylosurus crocodilis*
Taxa	Mkizi	Mullets
Taxa	Mkundaji	Mulidae
Taxa	Mnendele	Chirocentridae
Taxa	Msusa	Small Barracuda
Taxa	Mzia	Big Barracuda
Taxa	Mzia wengineo	Barracuda
Taxa	Ndadi	Chanidae
Taxa	Ndamacho	*Lutjanus gibbus*
Taxa	Ndoro	Barracuda
Taxa	Ndwaro	Swordfish
Taxa	Ngisi	*Uroteuthis duvauceli*
Taxa	Ngisi	Squid
Taxa	Nguru	Wahoo
Taxa	Nguru Kanadi	Kanadi Kingfish
Taxa	Nyamvi	Variegated emperor
Taxa	Pandu	Queenfish
Taxa	Papa	Sharks
Taxa	Paramamba	Haemulidae
Taxa	Pono	Scaridae
Taxa	Pweza	Octopus
Taxa	Sanje	Barracuda
Taxa	Sanje ndoro	Barracuda
Taxa	Taa	Rays
Taxa	Tasi	Siganidae
Taxa	Udufi	*Acetes* spp.
Taxa	Vibua	Mackerel
Taxa	Zagazaga	Others
Vessels	Boti	Plank boat with outboard engine
Vessels	Dhow	Dau
Vessels	Mashua	Plank boat with sail or engine

(*continued on next page*)

Table A.1 (*continued*)

Description	Swahili	English
Vessels	Miguu	Legs
Vessels	Mtumbwi	Canoe
Vessels	Ngalawa	Outrigger propelled by sail
Vessels	Ngwanda	Different keel from Mashua

Table A.2
Gear names and descriptions for all vessels recorded in the BMU data.

Gear Name	Description
Crabline	Handline but specifically for crab
Dig	Digging with hands or a toll, generally for crabs
Diving	Fishers dive and collect fish
Gillnet	Passive net that is left underwater
Halfbeak net	A form of gillnet with mesh for small taxa
Hand and Longline	Some combination of handlines and longlines
Handline	Fishing line with baited hook
Longline	Long fishing line which fishes passively underwater with baited hooks
Net	Similar to gillnet but is somehow different
Prawn seine	Seine with small mesh for prawns
Ringnet	Similar to a purse seine
Seine	Large net that requires active fishing
Shark net	Gillnet with large mesh for larger taxa
Spear	Wooden pole with pronged metal tip
Thrown handline	Similar to handline, perhaps similar to rod and reel. Unknown exactly
Traps	Basket baited traps

Table A.3
Mean ± standard deviation of taxa value (USD) per kilogram in Pangani and Rufiji, Tanzania, 2014–2017. When no standard deviation is provided next to the mean, it denotes that all recorded values were equal.

Species	Pangani Mean ± SD (USD)	Rufiji Mean ± SD (USD)
Acanthuridae	1.06	0.95 ± 0.30
Acetes spp.	NA	0.45
Barracuda	1.25 ± 0.16	0.99 ± 0.18
Big Barracudas	1.74 ± 0.21	NA
Black Lutjanidae	1.79 ± 0.11	NA
Bluestripe/Blackspot Snapper	NA	1.14
Carangidae	1.75 ± 0.21	1.08 ± 0.35
Catfish	0.90 ± 0.11	0.45
Chije	1.48 ± 0.48	NA
Chirocentridae	1.59	1.11 ± 0.09
Coelacanth	NA	1.44 ± 1.30
Crabs	1.61 ± 0.41	2.47 ± 1.09
Cuttlefish	1.52 ± 0.13	NA
Gerridae	1.75 ± 0.25	0.94 ± 0.05
Haemulidae	1.66 ± 0.19	1.14
Hemiramphidae	1.36	NA
Herija	1.82	NA
Humphead/Emperor Red Snapper	NA	1.14
Kanadi Kingfish	1.89 ± 0.13	NA
Lethrinidae	1.89 ± 0.14	1.14
Lobster	15.47 ± 5.35	NA
Lutjanidae	NA	0.95 ± 0.09
Mackerel	1.67 ± 0.13	1.09 ± 0.19
Mahi mahi	1.59	NA
Mulidae	1.46 ± 0.29	NA
Mullets	1.82	1.13 ± 0.04

(*continued on next page*)

Table A.3 (*continued*)

Species	Pangani Mean ± SD (USD)	Rufiji Mean ± SD (USD)
Mwekupe	1.36	NA
Octopus	1.77 ± 0.20	NA
Parata	1.82	NA
Platacidae	NA	1.14
Platycephalidae	NA	0.45
Prawns	2.16 ± 1.59	2.29 ± 0.40
Queenfish	1.14	0.89 ± 0.26
Rays	0.74 ± 0.38	0.91 ± 0.35
Red Snapper	5.28 ± 7.08	NA
Sardines	4.32 ± 2.24	0.45
Scaridae	1.16 ± 0.14	1.14
Scombridae	1.93 ± 0.12	NA
Serranidae	1.55 ± 0.23	1.05 ± 0.21
Shad	NA	1.14
Sharks	1.48 ± 0.63	0.84 ± 0.37
Siganidae	1.62 ± 0.40	NA
Small Barracuda	1.52 ± 0.26	NA
Squids	1.59	NA
Squirrelfish	1.73 ± 0.20	NA
Swordfish	1.82	1.14
Thumbprint Emperor	1.69 ± 0.16	1.02 ± 0.23
Tiger Prawn	NA	2.36 ± 0.56
Tuna	2.21 ± 0.23	NA
Tylosaurus crocodilis	1.36	NA
Uroteuthis duvauceli	3.19 ± 4.96	NA
Variegated Emperor	1.59	1.75 ± 1.63
Wahoo	1.79 ± 0.41	1.09 ± 0.19
Wayo	0.91	NA
Yellow Banded Emperor	1.71 ± 0.18	1.14
Yellowtail Scad	1.82	NA

Appendix B. Supplementary data

Supplementary data related to this article can be found at doi:10.1016/j.ocecoaman.2018.06.015.

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