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Recent rise in exploitation of Tanzanian octopuses: a policy and management challenge

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Abstract

The artisanal octopus fishery is important for the coastal communities in Tanzania. In this work the octopi landing data from the United Nations Food and Agriculture Organization (FAO), Ministry of Livestock and Fishery Development (MLFD) and trade statistics from Comtrade of the United Nations were analysed. The FAO dataset show that from 1980 to 2017 annual octopus landings stayed below 2000 tons until 2018 when the catch increased to 2864 tons, and doubled to 5,687 tons in 2019. FAO datasets show large catches in 1995, 2003 and 2019, with 2019 recording the largest catch. For both Comtrade and MLFD export statistics, approximately 5,818 and 2,254 tons of octopus were exported globally from 2018 to 2020 with an equivalent value of approximately 13 and 19 million US$ respectively. Portugal was the largest importer of Tanzanian octopi, followed by Turkey, Italy, Spain, Netherlands, Israel, France and Panama. The current management interventions relating to octopi are presented, including the challenges needed to be addressed for sustainability of the octopi fishery. Voluntary octopi closures indicated some signs of success, but an in-depth assessment of the associated effects is required. The study recommends a need for verification mechanisms to ensure consistency of FAO and MLFD statistics, stock assessments, *in-situ* research on recruitment patterns of octopi, as well as innovation and research in designing sustainable fishing gear to support development of policies for sustainability.

Keywords: artisanal, fishing, sustainability, trade

Introduction

Octopi forms an important fishery for coastal communities along the coast of Tanzania and the Western Indian Ocean (WIO). In mainland Tanzania approximately 150 tons (10 % of the total landing) is consumed by the local community annually, and a significant proportion (nearly 1500 tons, or 90 %) is exported to the international markets mostly in Europe and Asia (Guard and Mgaya, 2002; Rocliffe and Harris, 2016). To ensure the effective governance and sustainability of the fishery, it is important to understand the biology of the species involved, the socio-economic impacts of the fishery and conduct catch assessments from time to time to better inform fishery management.

Artisanal octopus fishers use gleaning, spears, traps, trawlers and pots (Van Nieuwenhove *et al.*, 2019). Gleaning is a technique applied mostly by women and children where they walk along the exposed shores and reefs during low tide hunting for octopus using sharp sticks.

The Tanzanian artisanal octopus fishery grew over the last decades due to a rise in international market demand and price paid for octopus (FAO, 2017).

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In turn, the artisanal fishermen responded by increasing fishing effort and changed their focus from local markets to also supply the international markets (Humber *et al.*, 2006). TANPESCA, Bahari Foods and Alphakrust are the main companies on the mainland annually, equivalent to about US$ 6.8 million (Rocliffe and Harris, 2016). The important international buyers during the same period were Portugal, Italy, France, Mauritius and Spain.

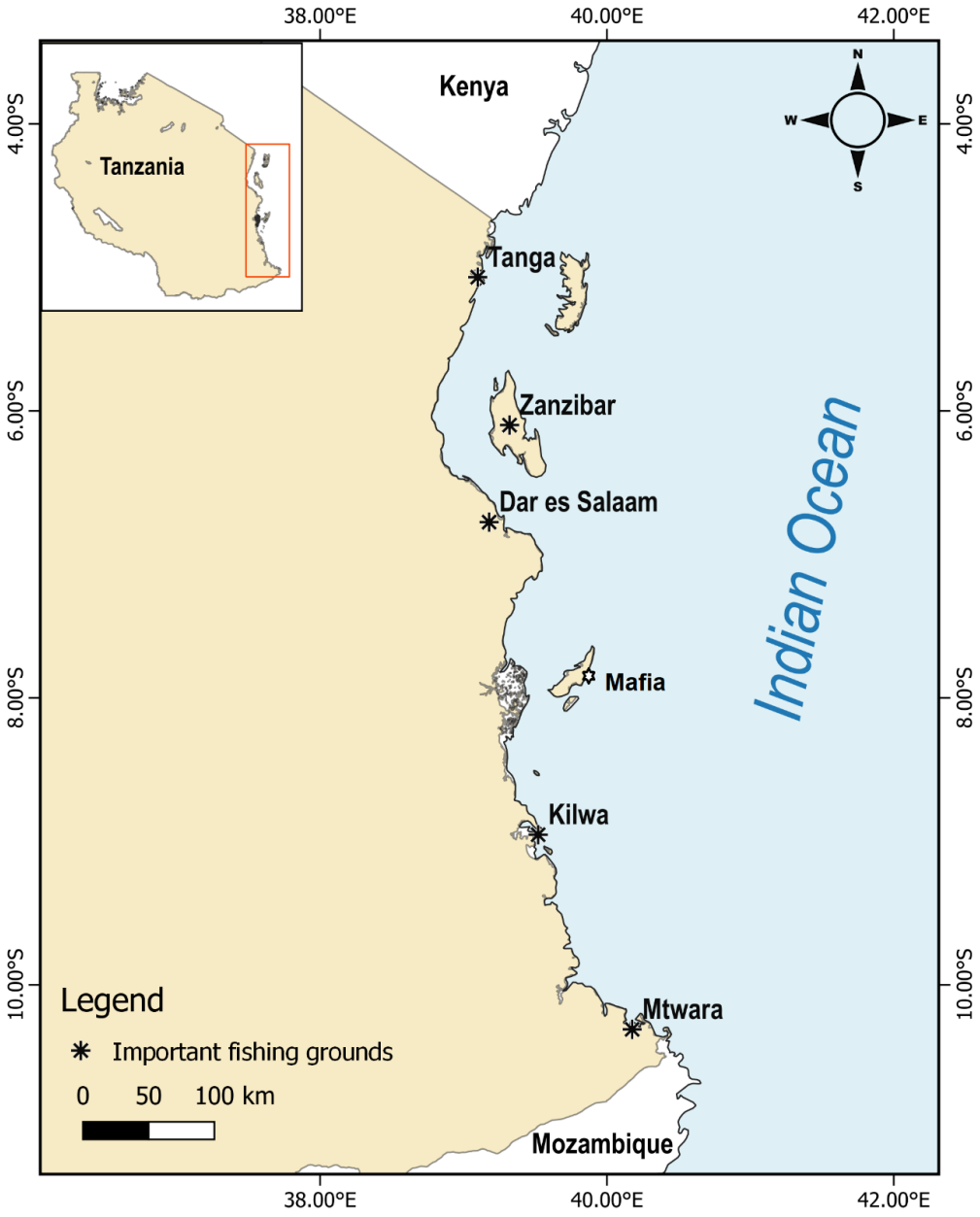

Figure 1. The coastal waters of Tanzania where the data originated. Some of the important octopus fishing grounds are concentrated in the sites marked with an asterisk, and include Tanga, Zanzibar, Dar es Salaam, Mafia, Kilwa and Mtwara.

that buy octopus from artisanal fishers, process and export to foreign markets (Anderson, 2014 as cited in Rocliffe and Harris, 2016). Information on recent (2018 - 2020) annual exploitation rates is lacking. Previous reports indicate that from 2008 to 2012 Tanzania exported approximately 1,500 tons of octopi In Zanzibar however, the main market is tourists and a smaller proportion (about 10 %) of the catch gets exported elsewhere (Pandu, 2014 as cited in Rocliffe and Harris, 2016). Due to its dependency on the tourism market, the octopus fishery in Zanzibar was severely impacted by the Covid-19 pandemic.

Perry *et al.* (1999) proposed three types of management strategies to safeguard the cephalopod fisheries: (i) catch regulation; (ii) size/sex limits; and (iii) control of fishing. As opposed to the large-industrialized fisheries, the artisanal octopus fishery consists of hundreds of fishers, making it challenging to implement effective management. Hence, in developing countries a combination of the three strategies is applied.

In Tanzania the octopi catch usually includes the two main species: the big blue octopus *Octopus cyanea* Gray, 1849; and the common octopus *Octopus vulgaris* Cuvier, 1797 (Guard, 2009; Pandu, 2014). *O. cyanea* is the larger species with a reported mean and maximum weight of 6 kg and 11.7 kg respectively (Guard and Mgaya, 2002). *O. cyanea* dominates the catch and can make up to 99 % of overall octopus landings (Guard and Mgaya, 2002). Research on life history, growth dynamics and the reproduction cycle of *O. cyanea* indicates that a time window (s) exist where short-term closures can have a positive effect on the fishery; especially when the females are nesting and during the period which the growth is exponential (Van Heukelem, 1973; Caverivière, 2006; Raberinary and Benbow, 2012). Thus, several experimental periodic octopus closure initiatives were established at sites in Tanzania and in other areas of the WIO. Reports show that the closures resulted in increased catch and income in the communities, although these benefits disappeared a few days after the opening (Benbow *et al.*, 2014).

This study analysed the octopi catch statistics from the Food and Agriculture Organization of the United Nations (FAO) between 1908 and 2019, annual octopus landing from the Ministry of Livestock and Fishery Development (MLFD) of the United Republic of Tanzania, and the octopus export statistics provided by Comtrade of the United Nations to report on the exploitation rates, trading, and recommendations to avoid misinformation and improve consistency of the data. Furthermore, the study explored the current management tools in place, and gaps that need to be closed to improve sustainability of the octopus fishery.

Methodology

Study area

The study assessed octopus landings and export data from Tanzania (Fig. 1). The country's waters are under the influence of the East African Coastal Current (EACC) flowing from the south toward the north of Tanzania. The region is affected by monsoon winds. The southeast (SE) monsoon occurs between May and September, and the northeast (NE) monsoon prevails from November to March (McClanahan, 1988). The country contains reef patches and shores supporting several fisheries and significant biodiversity. The main artisanal octopus fishing grounds are located in Kilwa, Mtwara, Mafia, Zanzibar and Tanga (Fig. 1; Anderson, 2014 as cited in Rocliffe and Harris, 2016).

Fisheries and octopus trade statistics

Octopus fisheries catch data were obtained from the FAO catch statistics (https://www.fao.org/fishery/statistics/, retrieved on 6 May 2021). The portal contains octopi catch data recorded between 1980 and 2019. Furthermore, the octopi export trade data were obtained from the United Nations Comtrade database (https://comtrade.un.org/data, accessed on 13 June 2021). All octopi product codes that represent octopus were selected in the Comtrade database search. The items included: 1. code 030751 for live fresh, or chilled octopus; 2. 030752 for frozen octopus; 3. 030759 for dried, salted, in brine or smoked, cooked or not before or during the smoking process; and 4. code 160*555* for prepared or preserved octopus. To assess the consistency of the dataset records from the FAO and Comtrade databases, the available annual octopus fishery statistic reports from the fishery department in Tanzania were consulted (MLFD 2003; 2008; 2011; 2013; 2014; 2015; 2016; 2018; 2019; 2020). The reports contained annual octopus landing and general yearly exported amounts that were used for validation and comparison.

Octopus fishery management in Tanzania

Existing relevant national management tools such as the Fisheries Act number 22 of 2003, the Fisheries Regulations of 2009 (G.N. No. 308), The Fisheries Regulations Amendment (GN.No. 492 of 3/7/2020) and the Fisheries Policy of 2015 were reviewed. An intensive literature review was conducted to provide a better understanding of the areas that need more attention to achieve sustainability of the octopus fishery.

Results

Octopus fishery and landings

FAO reports total catch for the whole of the United Republic of Tanzania, including the landings from the Zanzibar archipelago and Tanzania mainland. The total catch reported by FAO is therefore combined from the two territories (Fig. 2). Results show that the octopi catch in Tanzania increased from 483 tons in 1990 to 5,687 tons in 2019. Tanzania remained the top producer of octopi in the whole of the WIO region followed by

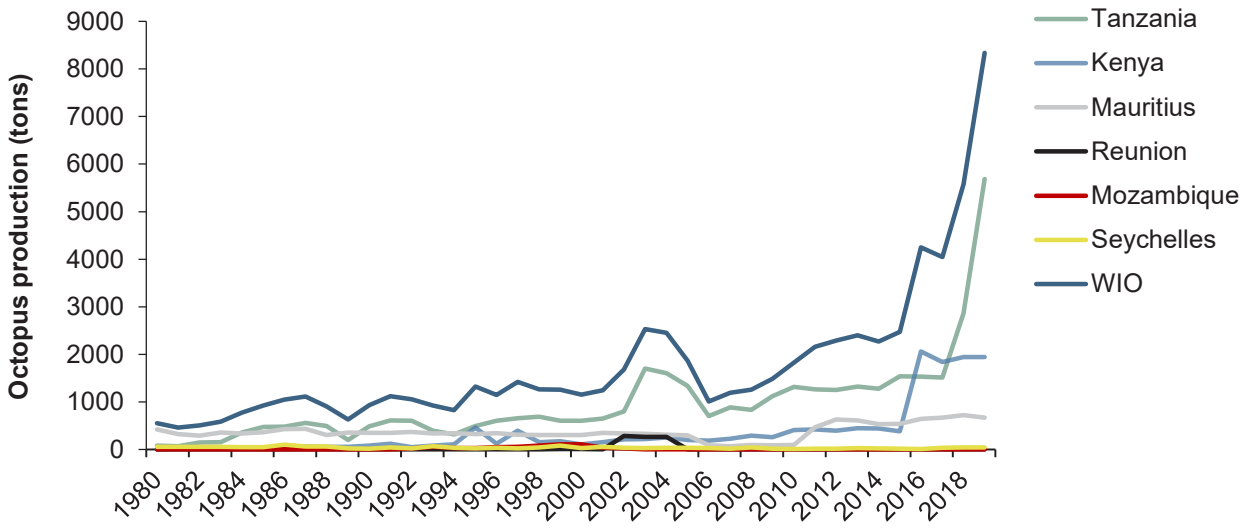

Figure 2. Octopus landing in Tanzania and the WIO region covering the period between 1980 and 2019. Source: FAO Fisheries and Aquaculture Department portal (https://www.fao.org/fishery/statistics/, retrieved on 06th May 2021).

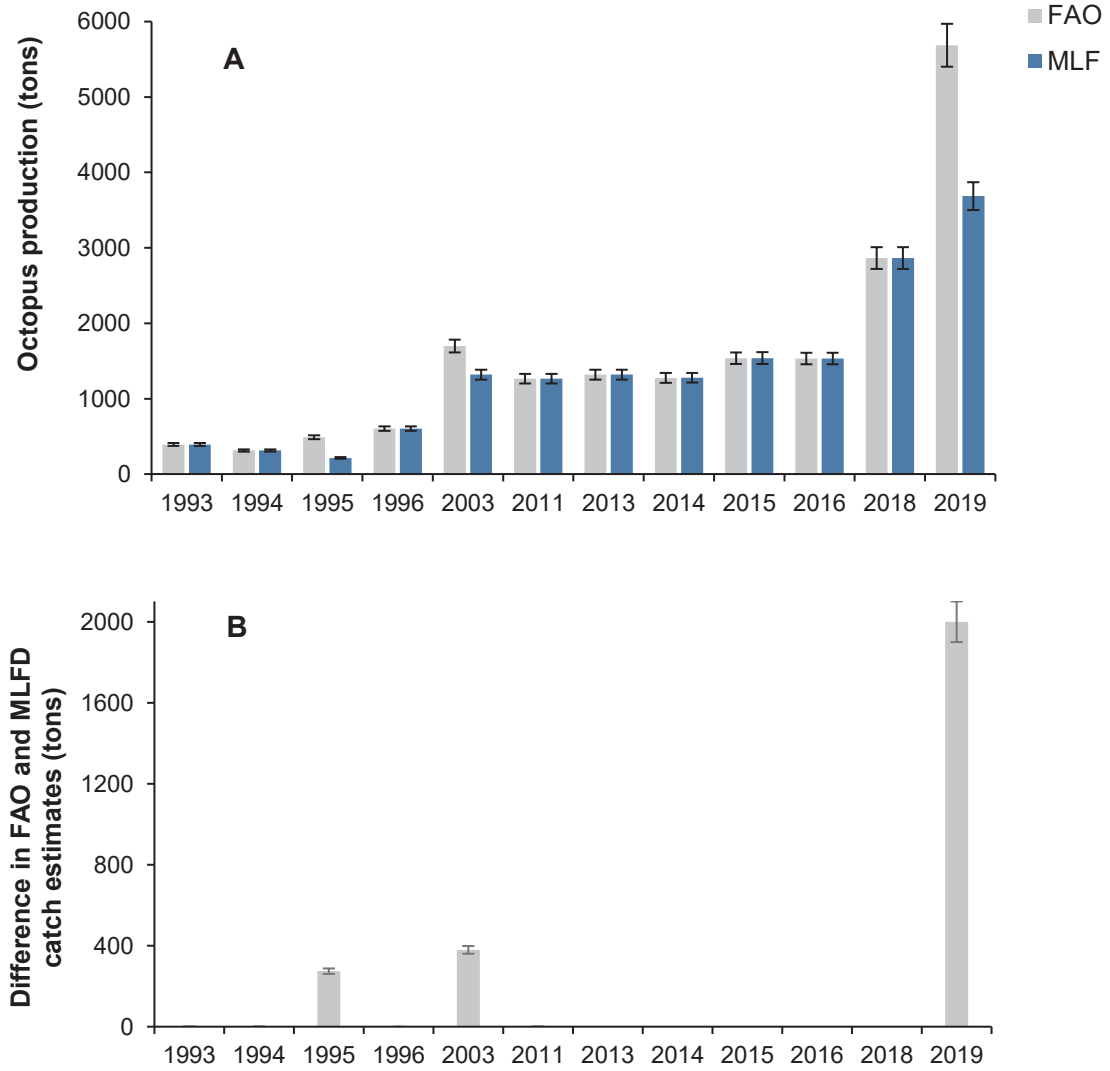

Figure 3. [A] Octopus catch statistics as reported by the Ministry of Livestock and Fisheries Development (MLFD) and the FAO Fisheries and Aquaculture Division. [B] The differences in catch between the two reporting entities. Note that there were notable catch discrepancies in 1995, 2003 and 2019. In 2019 for instance the FAO reported around 2000 tons higher than the MLFD. Sources: MLFD and FAO Fisheries and Aquaculture Division.

Kenya and Mauritius. In Tanzania, octopi production peaked at 1,700 tons in 2003, before decreasing to 703 tons in 2006. Since then, the landings rose steadily, reaching 1,251 tons in 2012, 2864 tons in 2018, and increasing rapidly to 5,687 tons in 2019.

The comparison between the records from FAO and MLFD are presented in Figure 3. Both datasets indicate increased octopi exploitation in the years 2019 and 2020. However, there are discrepancies in the data from the two reporting agencies. In 2019 FAO reported an annual catch production of approximately 5,687 tons and the MLFD recorded approximately 3,687.08 tons of octopus, with over 2000 tons difference. Notable differences in reporting were also found in the years 1995 and 2003 (Fig. 3).

Export market

The export data from the United Nations Comtrade platform covering the years 2021 to 2017 are presented in Table 1. According to Comtrade, Tanzania exported approximately 677, 1,681 and 3,460 tons in the years 2020, 2019 and 2018 with values of 3,384,721, 8,699,260 and 1,323,378 US$ in those years respectively. Thus, between 2018 and 2020 a total of 5,818 tons of octopus were exported from Tanzania to elsewhere, with

Table 1. Top countries importing Tanzania octopi per year from 2018 – 2021. Data were retrieved from Comtrade 2022 of the United Nations and the MLFD (MLFD 2018; 2019; 2020).

Year	Partner	Comtrade		MLFD	
		Quantity (Kg)	Trade value	Quantity	Trade value
2021	Portugal	310920	2370971		
	Italy	58968	533255		
	Turkey	19225	138204		
	Kenya	1290	4536		
	United Kingdom	11	31		
	Sub-total	**780828**	**6094003**	**N/A**	**N/A**
2020	Portugal	291409	1509280		
	Turkey	23036	68040		
	Spain	21060	105300		
	Kenya	1785	6729		
	Uganda	1200	2960		
	Sub-total	**677014**	**3384721**	**373,090**	**5,205,979**
2019	Portugal	833900	4327187		
	Turkey	4660	13980		
	Kenya	2010	7951		
	Rwanda	75	510		
	Sub-total	**1,681,290**	**8699260**	**1,048,580**	**14,164,387**
2018	Portugal	700202	193476		
	Israel	288840	12473		
	Netherlands	191254	25378		
	Spain	156002	12931		
	Turkey	116000	80033		
	Italy	105300	67785		
	Sub-total	**3,459,620**	**1,323,378**	**832,340**	**10,692.53**
2017	Portugal	671820	2828852		
	Italy	168930	705654		
	France	24000	231360		
	Panama	21060	63180		
	Turkey	13000	32500		
	Sub-total	**1,799,914**	**7,732,430**	**N/A**	**N/A**

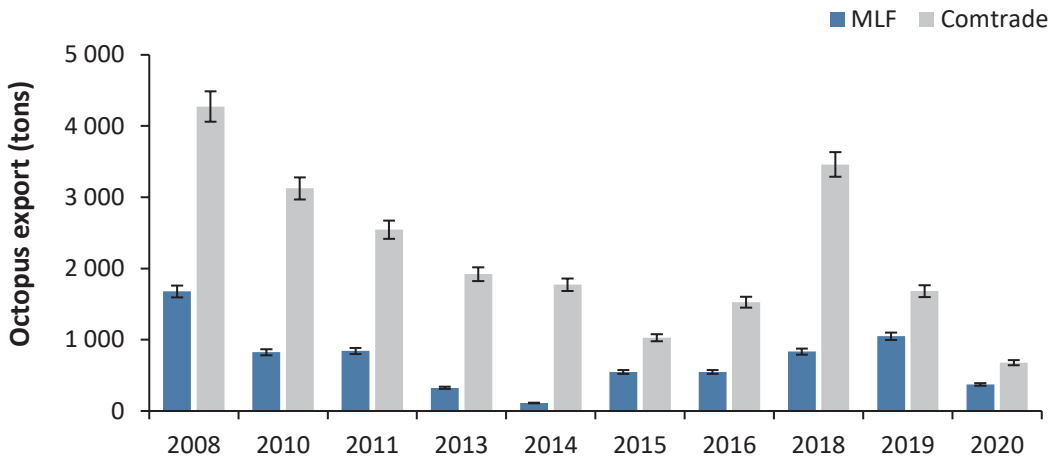

Figure 4. Recorded octopus exports (tons) as reported by the Comtrade and the MLFD. Note that the MLFD is consistently lower than the Comtrade data during this period, with the largest difference of approximately 2500 tons in 2018.

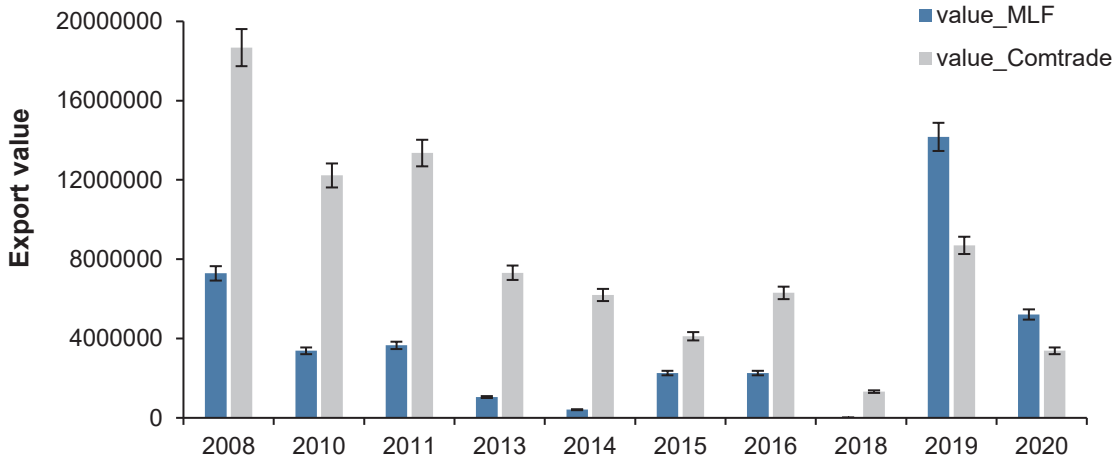

Figure 5. Octopus export values as reported by the Comtrade and the MLFD. The MLFD started recording larger values for octopus exports compared to Comtrade in 2019 and 2020. This is the period for which the MLFD recorded a larger catch of over 2000 tons.

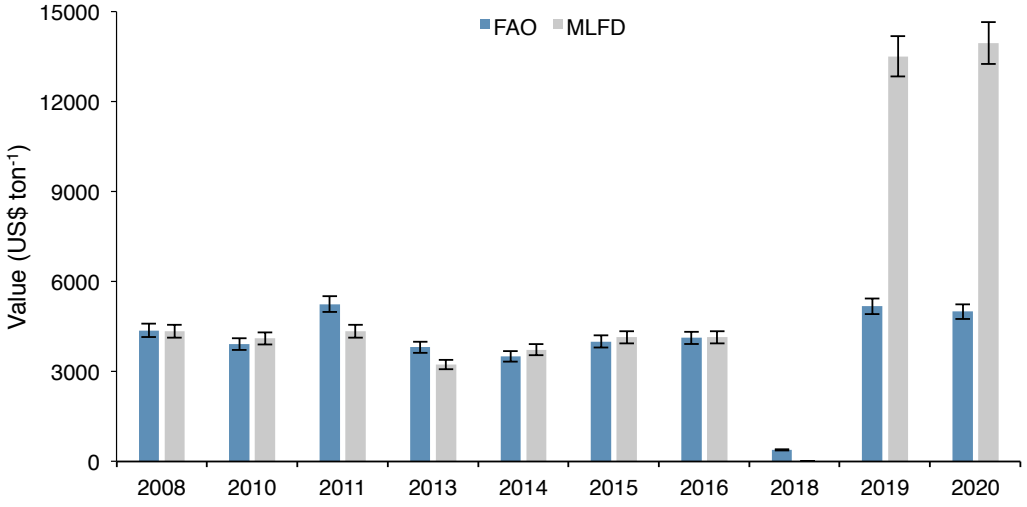

Figure 6. The value (US$) per ton of exported octopus recorded by FAO and the MLFD.

an equivalent value of around 13 million US$. The MLFD datasets reported estimated amounts of 373, 1,048 and 832 tons with values of 5,205,979, 14,164,387 and 10,692.53 US$ consecutively in these same years (Fig. 5). Therefore, a total of 2,254 tons of octopus valued at an estimated 19 million US$ were exported to other countries from 2018 to 2020. For both reporting entities, the amount exported was smallest in the year 2020, mainly due to the Covid19 pandemic. In the past five years, Portugal remained the leading importer of the Tanzanian octopi, reaching nearly half the total export amount in 2019 (Table 1). The other important importers between 2017 and 2020 were Turkey, Italy, Spain, Netherlands, Israel, France and Panama. In addition, a small proportion of octopi were shipped to the regional market in Eastern Africa reaching Kenya, Uganda and Rwanda.

The differences in the annual exported amount reported by Comtrade and MLFD is illustrated in Figure 4. The annual exports recorded by Comtrade were consistently larger than the MLFD. Both datasets

Table 2. Summary of octopus fishery management interventions and effectiveness

Intervention	Remark on effectiveness
Size limit: The Fisheries Regulation 59 (1) and its amendments of 2020 established an octopus fishing and handling size limit of 500 g. The regulation 59 (3) provides that no person shall trade or export processed octopus below the limit of four hundred and forty grams.	The fishing techniques are non-selective. Although exporting industries follow the rule, the undersized octopus are consumed locally.
Closed Season: The Fisheries Act No 22 of 2003 Section 17 (g) gave mandate to the Minister of Fishery to establish closed seasons, prohibit certain fishing techniques and species of fish. In some communities, the closure can be initiated voluntarily by the respective village upon agreement among themselves.	Closed seasons by top-down mandate is implemented mostly in other fisheries, the voluntary community octopus closure is now popular in Tanzania.
Management Zones: The Fisheries Regulation of 2009 in the Section 17 provided a mandate to the minister to initiate measures to ensure sustainable management of the fishery such as prohibition of fishing in certain areas. The regulation allows the minister to initiate controlled areas such as critical and potential breeding areas.	The regulation is essential, providing room for immediate conservation actions when a potential critical area is identified for biodiversity protection.
Access to Fishing (licensing): The Fisheries Act No 22 of 2003 in the Section 22 established a license requirement for anyone before undertaking fishery activities such as fishing, marketing, processing and or production of fishery related products. The license is provided by the Director or authorized officer. Requirements of license apply also to the fishing vessels and traders.	The regulation has succeeded to control fishing, but a more detailed examination is required to assess the effectiveness. For instance, children also collect octopuses at low spring tide, as a part of cultural practices.
Compliance and law enforcement: Fisheries Act No 22 of 2003 in the Section 17 gives mandate to the minister to take necessary measures to ensure sustainability of the fishery resources, the interventions related to enforcement, monitoring and surveillance. Section 32 (1) provides for the establishment of the surveillance and control unit. It also directs mechanisms that enhance participation of communities and other entities through agreements in national, regional and international arena.	Law enforcement has been challenged by limited resources (boats, fuel, and compensations), and capacity of the surveillance team in the villages to ensure reefs are well protected against unsustainable fishing practices.
Co-management arrangements (the Beach Management Units or BMUs): Fisheries Regulations, 2009 (13) provides for the establishment of the co-management structure from within the members of the fishing community to assist in activities like surveillance, control and catch inspection. Their roles also extend to data collection on 10 days of every month.	A good participatory approach, but the infrastructure and capacity of BMUs needs to be enhanced to improve their contribution to sustainability.
Marine Protected Areas: Marine Parks and Reserves Act No. 29 of 1994 (Section 8 (2) and Section 10 in particular provides a guide to establish the Marine Protected Areas (MPAs) for conserving biodiversity or at areas displaying features of significance such as historical, scientific or critical habitat values.	The approach is amongst the successful approaches, but more research and activities to enhance resilience of the ecosystems are needed.
Octopus fishing closure: These are self-driven participatory approaches when the community agree to implement a closure in their respective reef (s) with the goal of obtaining an improved yield and enhancing ecological benefit. They can be a pathway toward more concrete actions like establishment of new Marine Protected Areas.	The system worked best in remote areas with less population pressure. A more detailed assessment of the social-ecological benefits is needed. Program leads should use the best available science on recruitment of octopus for best results.

showed a difference of approximately 2000 tons between the years 2008 and 2013 (Fig. 4). In 2018, there was a discrepancy of over 2500 tons between the data reported in MLFD (832.34 tons) and Comtrade (3,459.62 tons) databases. There was a reduction in the exported catch recorded by the two entities in the years 2019 and 2020, which is likely a result of the Covid 19 pandemic. While Comtrade reported higher values of octopi per ton traded between the years 2008 and 2018, the MLFD recorded higher values per exported octopus (tons) in 2019 and 2020 (Fig. 6).

Existing governance tools and arrangements for octopus fishery management in Tanzania

The octopus fishery in Tanzania is mainly guided by the Fisheries Act number 22 of 2003, the Fisheries Regulations of 2009 (G.N. No. 308) with its amendments (GN.No. 492 of 3/7/2020) and the National Fisheries Policy of 2015. The Fisheries Act established a co-management system within the local communities called Beach Management Units (BMUs). The BMUs have been given a mandate to oversee the fishery in the fishing grounds and their respective landing sites in consonance with higher level fisheries management plans (Fisheries Act number 22 of 2003) and in consultation with the respective fishery officers. Their roles include collection of catch data, monitoring, control and surveillance, among others. As one of the control measures of fisheries that also applies to octopi, the Fisheries Act of 2003 requires that any person(s) conducting fishing activities should have a valid licence in accordance with the Act and Regulation.

To ensure sustainable exploitation of octopuses, the Fisheries Regulations of 2009 established a recommended allowable minimum octopus size of 0.5 kg (MLFD, 2009). The regulation is however not often enforced, and authors referred to it as 'voluntary' (Sauer *et al*., 2021). One of the challenges is that the methods used by fishers remained non-selective, such as the use of spears (Table 2). In most cases, fishers can injure or even kill undersized octopuses when they are still in the den before knowing the size, and therefore they don't find it logical to discard the octopus smaller than the size limit. Thus, individuals below the recommended weight are often harvested. The National Fisheries Policy of 2015 provides a guide for enhancing sustainable fisheries and management of aquatic resources. It provides the pathway for fishery control measures for sustainability, processing, value addition and trade.

Discussion

Octopus exploitation and trading

In this study it was found that, based on both data sets, the catch was above 2000 tons in 2018 and 2019. These findings differ from the Rocliffe and Harris (2016) where the FAO datasets from 2008 to 2012 were analysed, and showed that the annual octopi catch in Tanzania was below 2000 tons, yet still showed the important contribution of octopus to the economy and coastal livelihoods (Rocliffe and Harris, 2016).

Larger octopus landings in the FAO as compared to the MLFD datasets could be a result of lack of validation and/or random errors. The recent increase in catch could be due to elevated fishing effort over time and/or enhanced data recording (FAO 2017; Van Nieuwenhove *et al.,* 2019). However, these findings should be treated with caution because catch statistics from MLFD, FAO and Comtrade are likely conservative estimates (Rocliffe and Harris, 2016). The octopus fishery in Tanzania is affected by illegal, unregulated and unreported fishing. Thus, under-reporting of the catch makes it difficult to track the fishery products to meet certification and traceability requirements. The reported estimations are considered as underestimations, and more effort needs to be made to support catch recording at various fishing sites in Tanzania. Data challenges and underestimation has been a challenge in various fishing localities in the world, and reconstruction of the data could be an option to address this (Bultel *et al*., 2015). Belhabib *et al.* (2015) for instance, re-analysed catch records provided by the Republic of the Gambia to the FAO and found that the corrected catch data was double the original reported values.

In this study it was found that the major importers of octopus between 2018 and 2020 were Portugal, Italy, France and Spain, in addition to The Netherlands and Israel which were not reported by the previous study (Rocliffe and Harris, 2016). This indicates an expansion of the Tanzanian octopus market with implications for fishery management and sustainability.

Inconsistence in the MLFD and FAO datasets

In this study there were discrepancies in the catch statistics data as reported by the FAO and the MLFD. But because MLFD supply these data to the FAO, the observed difference could be caused by lack of good coordination between these bodies in providing the best estimates for octopus production, and limited validation, verification and inspection. There is also a

challenge with regards to octopus species identification, with reports suggesting that *Octopus cyanea* constitute over 90 % of landings (Guard and Mgaya, 2002) which also includes species like *O. vulgaris*, the MLFD statistics recognize only the white-spotted octopus *O. chromatus*. The FAO regard the whole octopi catch as the big blue octopus *O. cyanea*, but *O. vulgaris* has been found in Tanzania and other cryptic species exist in the WIO region (Guard and Mgaya 2002; Van Nieuwenhove *et al.*, 2019).

As for many other artisanal fisheries, the octopus fishery in Tanzania can be regarded as data deficient and there is no available traceability system to track, measure and record all octopus caught at various fishing villages. Because the MLFD reports rely on the BMUs who collect all fishery and octopus data on ten days on average per month, it is suggested that the octopus exploitation in the country is likely larger than the amount presented in this work.

Filling the gaps toward sustainability

While there has been progress toward improving sustainability and certification of the octopus fishery in Tanzania (Rocliffe and Harris, 2016), further work is required to achieve social, economic and ecological goals. Although the Fisheries Act 22 of 2003 controls fishing activities through licences, there is a risk that without accurate understanding of octopi stocks, more licences could be granted than the stocks can sustain (MLFD, 2009; Rocliffe and Harris, 2016). There is therefore a need for better science to inform management on estimates of stocks abundance and the number of fishers (fishing effort) allowed, to avoid overexploitation. Although the fishers were advised to use wooden sticks for fishing to protect the health of consumers, a large proportion of fishers still use iron rods (Guard and Mgaya, 2002; Sauer *et al*., 2021; Robertson *et al*., 2018). The use of fishing pots has been recommended as a more sustainable and selective fishing method that can avoid smaller individuals (Sobrino *et al*., 2011), but preliminary findings from recent trials conducted at Kilwa by the Tanzania Fisheries Research Institute (TAFIRI) showed that the pots did not capture any octopus (Bigeyo pers. comm.), and more experiments are being undertaken to further understand this.

Although the voluntary periodic octopus closures enabled community empowerment and participation in the fishery (Emery *et al*., 2016), there is need for dedicated research to guide the process. The voluntary octopus fishing closures at Jojo and Songosongo, for instance, started without any reliable scientific evidence on the spawning and recruitment pattern of octopus (Silas, 2022). The timing for most of the of the fishing closures conducted in Tanzania did not align well with the available scientific evidence. Octopus recruitment occurs year- round. Guard (2003) reported that *O. cyanea* recruitment peaks occurred in September, with a second smaller aggregation in February, and through subtracting the estimated number of days before recruitment they estimated that the respective brooding periods were in June and December. Recently, Silas *et al.* (2021) documented two major recruitment peaks, in May and July for Jibondo and Bwejuu sites (Mafia archipelago) respectively. Both Guard (2003) and Silas *et al.* (2021) recruitment peaks and spawning were within the May – September period. Therefore, to attain the maximum positive effect, an octopus closure should be scheduled for between May and September. Through modelling the influence of environmental variables on octopus catch, Chande *et al.* (2021) recommended that the closure should begin one month earlier (April to July) and reopening should be in October and March after a successful recruitment. Thus, the traditional octopus fishery closure can be implemented during inter-monsoon (April) throughout the SE monsoon (May to September) period. However, there is a need for further experimental research on the influence of environmental variables on recruitment using field data and models. Understanding the effect of environmental variables on recruitment of octopuses using predictive modelling and more accurate data can help to better inform practitioners about the correct timing for the most successful octopus closure.

Measuring success of the octopus closure initiative can be challenging without clear predetermined metrics. Lindkvist *et al.* (2019) collected expert opinions in the WIO on how they defined successes of the past periodic octopus closure and concluded that all practitioners, including academia, viewed successes in three categories: economic, ecological and social. Economic success was viewed as a result of an increased income, economic conditions and trade opportunities in the communities. Ecological success was defined by increases in variables such as catch, individual size and catch per unit effort, in addition to positive effects on other marine species. Social success included acceptance by the coastal community, reduced conflicts and improved governance. Data should be collected from both closed

and open access sites to document the 'true' success of the experimental closure efforts in each category. Octopus catch increased after three months of closure at Songosongo, for instance (in 2018 and 2019), with large catches (10 and 19 tons respectively) after only a few days of harvesting (WWF, 2018). The benefit sharing was an issue because of intrusion of fishers from other nearby localities (Silas, 2022). The significant increase in catch could have been as a result of increased fishing effort of the fishers from the nearby villages. Furthermore, men are more involved in octopus fishing at relatively high waters using diving gears than women (Vanier, 2022). If an octopus fishing closure aims to establish a social success regarding gender equity, the program would need to incorporate these dimensions in measuring the associated positive effect. Clearly predefined goals (or metrics) and design would be needed to establish successes and compare the activities associated with closure against other possible applied management approaches.

Finally, improving marketing structure and infrastructure across the value chain can enhance the economic benefit in the local communities. During the octopus reopening at Kilwa, approximately 5 tons of the harvested octopus spoiled due to lack of readily available cooling facilities (WWF, 2021). In addition, the price during reopening at the landing beach and locally available markets reduced by approximately 8.8 %, from 1.83 US$ to 1.62 US$ (Silas, 2022). A management strategy that includes periodic closures should consider immediate and long-term risks, and the impacts on market prices.

Recommendations

With increasing fishing effort, driven by both local consumption and international markets, it is suggested that there should be a permanent plan to effectively collect and monitor the octopus catch and trade data. Because the information derived from the MLFD, FAO and Comtrade likely represent underestimates, there is a risk of overexploitation and misunderstanding the contribution of the octopus fishery to the economy and livelihoods of Tanzania. Determining the size of the octopus stock at different sites can guide fishery management towards preventing overfishing. This will require resources to collect more accurate catch and effort data, and to develop robust models with fewer assumptions and a better understanding of seasonal changes in stocks (Otero *et al*., 2005; Sauer *et al*., 2021).

Increasingly, there are trained data collectors, apart from BMUs, at the landing sites but most are not permanent and are subject to the duration of projects and programmes. The authors recommend that the government continues recording the octopus export trading data and make it publicly available. Without this, it would be difficult to ensure and maintain the sustainability of the fishery. There is a need to strengthen the enforcement and awareness of fishery regulations to ensure fishers comply with the existing laws and policies. Although fishers found it challenging to preselect specimens that were below the recommended size when the octopus was in a den, some fishers still harvest small octopus intentionally.

Conclusions

The study identified discrepancies in the catch statistics as reported by the FAO, MLFD and Comtrade. According to the FAO the annual octopus landings remained below 2000 tons until 2018 when the catch increased to 2864 tons, and to 5,687 tons in the year 2019. Both MLFD and FAO provided a signal of increasing exploitation of Tanzanian octopus but FAO recordings were higher in several years, particularly in 1995, 2019, and 2003. In 2019 FAO reported over 2000 tons higher than the MLFD recordings. The differences were also observed in the exported amount and values, with Comtrade and MLFD recorded a total of around 5,818 and 2,254 tons of octopus from 2018 to 2020 with an estimated value of 13 and 19 million US$ respectively. The existing interventions for octopus fishery management have had some degree of success, but work is needed in improving management infrastructure, data collection, research, innovation towards more sustainable selective fishing methods, law enforcement and improving capacity of the BMUs. While the octopus fishery closure could have ecological successes, they work best in less populated villages, and social and ecological successes require established regional metrics or guides for evaluation. The study recommends increasing investment to support BMUs in octopus management, ensure continuous data collection, verification and validation of the statistics between FAO and MLFD before reporting, and stock assessment to determine the exploitation status of the octopus at various fishing villages to inform the authorities to take the necessary measures to improve the fishery governance.

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