KENYA MARINE FISHERIES SOCIOECONOMIC PROJECT

COMPONENT 1

ENHANCED GOVERNANCE OF MARINE FISHERIES AND BLUE ECONOMY

Research Strategy

Octopus Fishery Stock Assessment

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1. OCTOPUS FISHERY

1.1. BACKGROUND

Octopus fishing is an important economic and subsistent activity, particularly for indigenous coastal communities in Kenya (Crona et al., 2015). The fishery is a key source of income, alternative livelihood, and animal protein (Jiddawi and Ohman, 2002). This is a typical reef fishery because Octopus are often hidden in small holes (dens) and crevices in the inter-tidal reef flats and subtidal inner reefs. A pointed stick (harpoon) or spear can be used to trigger the Octopus to grasp the stick. The Octopus can then be withdrawn from the den (Sauer et al., 2011). They are fished either by walking over the lower reaches of the intertidal reef flat or by snorkeling along the reef edge (Ngatunga 2009; Smith et al., 2010).

Octopus landings are often sold and processed locally, while some is exported to the European market (Guard et al., 2000). Being a low cost - low tech fishery and inexpensive, artisanal octopus fishing in Kenya was dominated by women and in some cases children are also involved in fishing. Indeed, it was one of the few sources of income for active women fishers in Kenya. While providing much needed income to local communities, the fishing intensity has markedly risen, placing greater pressures on the fishery. The increase in demand for Octopus in the local and international market (Erickson et al., 2012), has contributed to heavy fishing of Octopus along the coast of Kenya (Guard and Mgaya 2002). Indeed, men have been increasingly involved in octopus fishing in recent years due to the rise in demand and price.

Several management measures have been proposed to protect the fishery from overfishing and achieve sustainability. These include the introduction of a minimum size restriction of 10.8 cm (dorsal mantle length) per Octopus caught or traded (Kivengea 2014a). The 10.8 cm was selected as the minimum length restriction, as this is the size at which 50% of female Octopus are suspected to be mature. The Kenyan Fisheries Act Chapter 378 (McClanahan et al., 2005) also prohibit the use of spear gun in Kenya (Kenya Gazette Notice No. 7565 - 2001) – one of the main fishing gears used to target Octopus (Samoilys et al., 2011).

Despite its importance, little information is available on fished Octopus's ecology and life cycles, particularly in tropical regions. At present, most studies have been conducted in temperate or subtropical waters and concentrated on octopus biology or trawl fisheries (Hatanaka,1979), and not on traditional small-scale fisheries as practiced in Kenya. It is believed that local coastal communities of Kenya harvest three different species of Octopus; common Octopus (*Octopus vulgaris*), white-spotted Octopus (*Octopus chromatus*), and day octopus (*Octopus cyanea*) (Mshana and Sekadende 2014). Scientific reports in Kenya have referred to the species as *Octopus vulgaris* (van Hoof and Kraan 2017), yet biological studies have confirmed that 99% of the Octopus in Kenya is *Octopus cyanea* (Taylor 2012). The uncertainty in species identification call for more comprehensive identification studies using molecular approaches.

Fisheries managers in Kenya would like to pursue Marine Stewardship Council (MSC) certification for the octopus fishery (van Hoof and Kraan 2017). The council is keen on mapping octopus fisheries' sustainability and supply chains throughout East Africa to include these nations in the MSC certification fisheries program. To achieve this, a number of collaborative studies on the artisanal octopus fisheries in Kenya have been attempted in the past, albeit with limited success. This study's findings can potentially contribute to developing a sustainable octopus fisheries management plan and paving the way for inclusion in the Marine Stewardship Council certification process. The KEMSFED baseline study (Fulanda, 2018), makes the following recommendations as possible areas of intervention for the octopus fishery in Kenya:

- Establish an effective system for octopus catch data collection and analysis by strengthening the CAS program
- Training data enumeration in species identification and recording species-specific information for the Octopus fishery.
- Ensure regular scientific monitoring and evaluation of the fishery

- Conduct a risk-based analysis for the target species to identify the environmental impacts of the fishery to support the evaluation of the sustainability status of the fishery.

Within the proposed areas of intervention, the KEMFSED project will seek to pursue the ecological objectives relevant to octopus fishing to develop a management plan for the octopus fishery in Kenya.

2. AIM AND OBJECTIVES

2.1. Aim

The study's main aim is to provide a solid scientific baseline on the octopus fishery in Kenya to help ensure the ecological sustainability of the fishery. Information relating to *Octopus cyanea* and *Octopus vulgaris* biology, including fishing impacts, social importance, and dependence on the fishery, will support the development of a realistic and effective management plan for the fisheries.

2.2. Objectives

The study has the following specific objectives:

1. Determine the current state of the octopus fishery in Kenya

Activities

- 1.1. Conduct a retrospective analysis of existing data to evaluate the quality of the data for stock assessment
- 1.2. Describe the general life history of the common octopus species landed at the Kenyan coast, including reproductive biology
- 1.3. Train and utilize data enumerators to collect octopus catch and effort data from comparable sites
- 1.4. Develop a database for Octopus fishery catch and research data,

2. Determine the ecological impact and effects of fishing on the stocks to ensure that the fishery does not result in unsustainable levels for both the target and non-target species

Activities

2.1. Sample catch and effort data of the fishery for at least one year
2.2. Sample size-based indices from the landed species
2.3. Sample maturity data from the landed species
2.4. Perform a risk assessment to determine impacts on non-target species

3. Develop a precautionary harvest strategy for the Octopus fishery

Activities

3.1. Develop fisheries and habitat maps for the fishery
3.2. Estimate reference points and harvest rules for the fishery
3.3. Design fishery specific management recommendation for the fishery

4. Examine the socio-economic importance and dependence on octopus fishery

Activities

4.1. Analyze perceptions of octopus fisheries management benefits,
4.2. Investigate perceptions of future outcomes of octopus fisheries and management,
4.3. Conduct value chain analysis,
4.4. Collect data on markets, trade network and prices

2.3. Expected Outputs

1. Knowledge on sustainable yields and estimations of total yields, yields of the two species and current yields relative to sustainable yields
2. Awareness raised about sustainable yields and the status of octopus fisheries raised amongst communities
3. Recommendations for fisheries bylaws and co-management plans
4. Publication: Establishing sustainable yields and status of octopus fisheries in Kenya
5. Training materials, octopus fisheries data collection protocols
6. Monitoring data on octopus fisheries

7. Communities trained on monitoring octopus fisheries and ecology
8. Mapping of key fishing grounds for octopus fishery in Kenya

2.4. Expected Outcomes

1. Description of the stock status to provide information that can be used to formulate conservation and management recommendations for the fishery
2. Estimations of sustainable yields at project sites are determined and community knowledge is improved.
3. Community capacity in data collection is improved through training in monitoring octopus fisheries and ecology

2.5. Expected Impacts

We expect the overall impact of the project to be that the BMUs will develop sustainable fisheries management plans that are realistic about the state of the resource. This engagement and knowledge should also increase the perceptions that stakeholders have greater agency to be involved in achieving sustainability. The overall goal is that this project will produce an evidence-based mechanism for management in Kenya to protect an important fishery that benefits active male and female fishers. The specific impacts are as follows:

1. Sustainability is achieved through evidence-based management by fisheries scientists, managers, and fisher communities.
2. Continued provision of community benefits from octopus fishing including improved livelihoods and greater food security.

   Improved catches and well managed octopus fishery in Kenya

3. METHODS

The following methods are grouped into the major project activities that will contribute to achieving the nine objectives. The project will be highly participatory, and the work will involve participants from three Beach Management Units (BMUs), Kenya Marine and Fisheries Research Institute (KMFRI), and Kenya Fisheries Service (KeFS).

3.1. Study Area

The fieldwork will be carried out in Kwale, Kilifi and Lamu County. The study will be conducted over a two-year period at six research stations along the coast: Shimoni, Mwaepe, Bamburi, Uyombo, Mayungu, Shanga-Ishakani. Sites were chosen to represent three separate geographical areas along the Kenyan coast. All fishing activities for Octopus at these sites occur on adjacent coral reefs within the intertidal and inner subtidal zones.

3.2. Study Species

Two species i.e., *Octopus cyanea* and *Octopus vulgaris* will be assessed given that they are the most common and abundant species in the catches.

3.3. Sampling Methodology

3.3.1. Selection of Data enumerators

For the purposes of this study, commercial fishing data from the fishers and biological data will be sampled from each sampling site by a team of scientists from KMFRI. However, it is envisaged that local members of BMUs will be trained and utilized as data enumerators to collect octopus fisheries data from comparable sites to complement the scientific team from KMFRI. The goal is to identify, train, and utilize data enumerators to collect octopus catch and effort data from comparable sites to complement the scientific team. The data collection methods proposed will be designed to provide maximum information for fisheries assessment while being simple enough for local enumerators to learn quickly and continue with minimal supervision.

Once identified, the BMU data collectors, which will include a man and a woman in each site will be trained in the recording and measuring procedure for a period of three days and supervised to collect octopus fisheries data .The trainees will also participate in the proposed monthly catch monitoring that are described below.

3.3.2. Sampling design

The routine data collection by the BMU will cover approximately 20 days per month. It is important to note that Octopus fishing occurs when the water is low i.e., spring tides (low tides) in the intertidal reefs, and reefs are exposed. This means that BMU measurements and sampling of the length and weight of individual octopus can only take place for not more than 16 fishing days a month.

Given the short lifespan of Octopus species and sensitivity to environmental conditions, the sampling of Octopus should be undertaken over a shorter timescale as compared to finfish. Therefore, to minimize the obscuring effects of seasonal and environmental variability, sampling of both commercial and biological data will be conducted twice a week times per month to conform to scientific standards of sampling and ensure adequate characterization of the size compositions of the multiple cohorts.

During the periods of higher catches, intensive sampling (i.e. daily) will be considered and will include the collection of the total catch per fisher to investigate catch trends and maturity data, to facilitate the assessment of maturity trends and length composition data by cohort.

3.3.3. Fisheries measurements

The following information will be included in the data collection forms. Time of departure from landing site, gear used, time of arrival at fishing site, name of fishing site, time of return to landing site, length of time spent fishing. Fishing zone (intertidal or sub- tidal), weight of each Octopus in the catch (g) and size indices such as dorsal mantle length (cm) and total length (cm) by species and sex.

Total body wet weight (BW, g) will be measured using a top loading electronic balance. All length measurements including total length (TL, cm), dorsal mantle length (DML, cm), and ventral mantle length (VML, cm) will be measured using a measuring board/tape. Sex will be determined by observing of the presence of the spermatophoric groove and hectocotylus on the third right arm for males and absence of these features for females.. Total external gonad wet weight will be measured using an analytical balance. For detailed observations of reproductive organs, data on ovary and testis weight (OW and TW), oviducal complex weight (OCW), oviducal gland length (OLG), Needham's complex weight (NCW), and digestive gland weight (DGW) will be collected from lab specimens. A maximum of 50 gonads will be collected per site during sampling visits by the scientific team. Sampling and measurement of the length and weight of individual Octopus will be done for 10 days in every month.

3.3.4. Socioeconomics and scenarios

We propose to complete a series of social surveys that will directly address specific aspects of 1) perceptions of octopus fisheries management benefits, 2) perceptions of future outcomes of octopus fisheries and management, 3) value chain analysis, and 4) markets and prices. At each landing, we will sample using stratified (jobs) random sampling of stakeholders and households to attempt to capture >10% of the BMU members. First, the socioeconomic status of stakeholders using well-established household questionnaires used in many tropical fisheries (Cinner et al., 2009). In addition, we will examine perceptions of fisheries and governance effectiveness following methods of McClanahan and Abunge (2018, 2019). These two methods examine the perceived benefits of the various fisheries management options in relation to the octopus fishery. Finally, we will develop questionnaire specific to examine stakeholders' views of past, current, and future state of their villages and fishing landings from the lens of environment and sustainable use.

Surveys will be undertaken twice, at the beginning of the project and at >1 year after the project initiation to examine the stability and potential influence of this fisheries monitoring engagement program on the perceptions of stakeholders via their responses to these questions. These responses will be evaluated and used to better understand perceptions of the history of fisheries, current limitations to effective management, and expectations for the future. These data will be combined with information on the status of the fishery from the above measurements to develop a current understanding of the fishery that will be described to these communities towards the end of the second year of the project. The degree to which stocks either need to be rebuild or sustainably fished and the social capacities to manage them will be the focus of these presentations. From this information, we propose to develop plausible scenarios for discussion at the end of the project period. These scenario discussions will be used to make a final set of recommendations to stakeholder communities. These will then form the basis for building or revising the BMUs management plans depending of the state of their plans. The outcome will be to incorporate the recommendations into the BMU bylaws and inform the ongoing discussion on a national SSF policy.

4. DATA ANALYSIS

4.1. Fisheries yields

The annual catch will be estimated as the mean daily catch multiplied by the fishing days per year to analyze the temporal trends in catch and effort data. Catch Per Unit Effort (CPUE) will be expressed as kg/fisher/day (Muthiga and McClanahan (1987). To estimate the status of the octopus fishery, catch based assessment method will be applied to the historical catch data. The CMSY method will be used to calculate time series of the catch, biomass, exploitation rate and equilibrium curve of the two species. Given the challenge experienced in species identification in the historical data, a ratio-based framework will be adopted based on the current sampling regime to tease out the contribution of the two species in the overall catch. This will be then applied to the historical data to determine the relative delineation of the species in the total catch.

The CMSY approach will then be applied to the historical data, assuming that there will be sufficient variability in the catch trends. The CMSY approach is Schaefer production model, which assumes that the biomass delivering MSY is equal to 50% of the unfished biomass (Froese et al. 2017).

Resource status will be assessed by the comparability of the current fishing mortality rate with the optimum or the target (Fopt) and limit (Flimit) biological reference points (BRP) which will be delineated as: Fopt = 0.5 M and Flimit=2/3 M.

4.2. **Length-based evaluations**

The ShinyTropFish (version 0.9.1) based on the TropFishR package (version 1.7.0) will be used to estimate the growth and mortality parameters based on the length frequency data from modal progression and catch curve analysis using the ELEFAN_GA function (Pauly and David 1981).

Length-weight relationships will be examined using the power curve equation: $W = qL^b$ where W is the total wet weight (g), L is the dorsal mantle length (mm), b is the slope of the regression line, and q is the intercept on the Y-axis.

4.3. **Mortality Parameters**

The instantaneous total mortality rate (Z) will be computed from the linearized length-converted catch curve (LCC) (Pauly, 1987). Natural mortality will be calculated from the empirical formulae of Pauly 1980 by using a mean sea surface temperature of the fishing area. Mortality (F) will be expressed as F= Z - M and the exploitation rate (E) will be estimated as F/Z according to (Pauly and Munro 1984).

4.4. **Yield per recruit/ spawning biomass per recruit**

The length-based yield per recruit model (YPR) and SBPR will be used to evaluate the exploitation levels of the selected octopus species, which would result in optimum yield. With the growth parameters as the input, the reference levels Fmax (the fishing mortality, which produces the highest yield per recruit), F0.5 (the fishing mortality that results in a 50 % reduction of the biomass compared to the unexploited population), and F0.1 (the fishing mortality that corresponds to 10 % of the slope of the yield per recruit curve as a function of F when F=0. This is the F at which the marginal increase in equilibrium yield has dropped to 1/10 of its value when the stock was first exploited. Fmax is the fishing mortality rate that produces the maximum yield per recruit.

4.5. Maturity estimates

Sexual maturity will be determined on a 5-stage maturity scale for females and 3-stage maturity for males. A gonadosomatic index will be obtained using the following formula: GSI = Wo/(Wt - Wo) * 100 where Wo is the weight of the ovary and Wt is the total wet weight. For the purpose of ensuring that catch data is of the highest quality, validation tests will repeatedly conducted through the sampling period. Monthly length frequency catch data (LFCD) of *Octopus cyanea* and *Octopus vulgaris* will be analyzed.

5. REPORTING

The expected outputs, outcomes and impacts are detailed below. The project will also generate knowledge through the collection of ecological, fisheries, and social data of the dependent communities that is useful for management and for future comparative studies. The project will produce management recommendations that will provide stakeholders with various management scenarios that can be discussed and adopted in bylaws. It is expected that at the end of the project, there is an improved understanding by communities and managers about octopus fisheries, improved management skills from monitoring, and improved livelihoods and food security due to sustainable management.

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7. Annexes

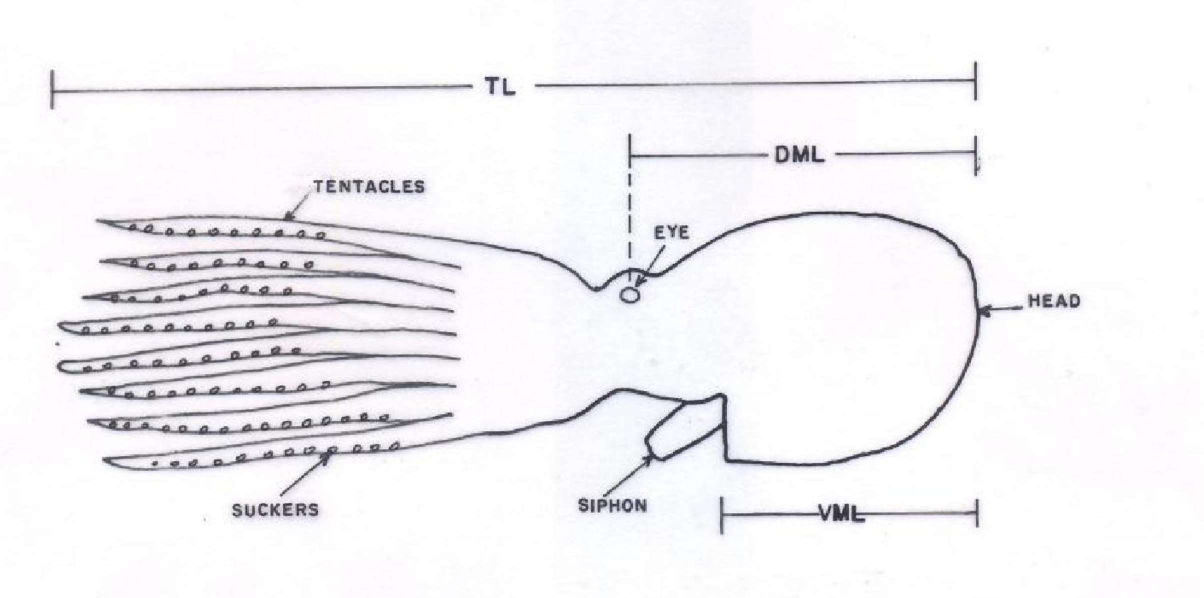

Fig 1. Length measurements of common Octopus; DML - dorsal mantle Length, TL - total body length, and VML - the ventral mantle length. Credit: (Sakaguchi et al. 1999)

OCTOPUS DATA COLLECTION FORM; CATCH AND EFFORT

Landing site……………………………………………………………………………………..

Date………………………………………………………………………………………………

Name of vessel/boat…………………………………………………………………………….

Vessel registration number (if applicable)…………………………………………………….

No. of fishermen per boat ………………………………………………………………………

Landings (kg) …………………………………………………………………………………….

Gear used ………………………………………………………………………………………..

Fishing time Day………………. Month………….. Hours…………………………………

Date and place of landings …………………………………………………………………….

No. of fishing operations ……………………………………………………………………….

BIOLOGICAL SAMPLING FORM

No.	Date	Area fished	Sex	Body Weight (g)	Total length (cm)	Dorsal Mantle length (cm)	Ventral Mantle length (cm)	Ovary/testis weight (g)

8. WORKPLAN AND BUDGET ESTIMATE

Table 1: Work plan and summary budget

Activity	Responsibilities	Year 1				Year 2				Budget summary (2-yrs)			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Objective 1: Kenya octopus fauna described													
A1.1 Molecular study to identify species present	BMUs, KMFRI												
A1.2 Awareness meetings on findings	BMUs, KMFRI, KeFS												
A1.3 Produce scientific publication	KMFRI, KeFS												
Objective 2: Ecology and life-history characteristics for identified species determined													
A2.1 Empirical study on ecology and life-history	BMUs, KMFRI, KeFS												
A2.2 Produce scientific publication	BMUs, KMFRI, KeFS												
Objective 3: Impact and effects of fishing on local Octopus cyanea and Octopus vulgaris stocks determined													
A3.1 Empirical study on fishing impacts on local Octopus	BMUs, KMFRI												

A3.2 Awareness meetings on findings	BMUs, KMFRI, KeFS												
Objective 4: Fisheries-gears interactions and the habitats determined													
A4.1 Empirical study on octopus fisheries-gears-habitats interactions	BMUs, KMFRI												
A4.2 Awareness meetings on findings	BMUs, KMFRI, KeFS												
A4.3 Produce scientific publication	KMFRI, KeFS												
Objective 5: Octopus fisheries and habitat maps developed													
A5.1 Develop fisheries and habitat maps for the octopus fishery	KMFRI												
Objective 6: Socio-economic importance and dependence on octopus fishery examined													
A6.1 Socioeconomic surveys	KMFRI												
A6.2 Produce scientific publications	KMFRI, KeFS												
Objective 7: Database of Octopus cyanea and Octopus vulgaris catch and research data developed													
A7.1 Develop database	KMFRI												
Fishery specific management recommendation developed													
A7.2 Develop	BMUs, KMFRI,												

recommendations	KeFS												
A7.3 Promote distribution of findings	BMUs, KMFRI, KeFS												
A7.4 Awareness materials & meetings on sustainability	BMUs, KMFRI, KeFS												
Objective 8: Data enumerators to collect octopus catch and effort data from comparable sites trained and utilized													
A8.1 Train community data enumerators	BMUs, KMFRI, KeFS												
A8.2 Expert and community monitoring and comparison of experts vs. community	BMUs, KMFRI, KeFS												
Produce a final project report	BMUs, KMFRI, KeFS												
BMUs = Beach Management Units, KMFRI = Kenya Marine and Fisheries Research Institute, KeFS = Kenya Fisheries Service													

Table 2: Detailed Budget

Table 3: The Fishery Team / Personnel

Participant Name	Responsibility:	Affiliation:
Dr Emmanuel Mbaru	**Team leader**	KMFRI
Dr Thomas Mkare	Team member	KMFRI
Ms Jane Nyamora	Team member	KMFRI
Ms Janet Mwangata	Team member	KMFRI
Mr Daniel Ocharo	Team member	KMFRI
Mr Boaz Orembo	Team member	KMFRI
Ms Faith Nafula	Team member/Intern	KMFRI
Mr. Fredrick Oketch	Team member/Intern	KMFRI
Ms. Faith Anyango	Team member/Intern	KMFRI
Ms Debline Mtana	Team member	Kilifi County
Mr. Emmanuel Diyo	Team member	Kwale County
Mr Kirathe	Team member	Lamu County

Sites	Personnel		
Shimoni			
Mwaepe			
Bamburi			
Uyombo			
Mayungu			
Shanga Ishakani			