The Artisanal Fishery for Octopus cyanea Gray in Tanzania

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Preliminary results for the artisanal fisheries of *Octopus cyanea* Gray (1849) in Tanzania are provided for the period April 2000 until June 2001. A total of 2546 individual catches and 15473 specimens were analyzed from 3 sites located at Tanga, Mafia Island, and Mtwara. Size range, average weight and catch per unit effort (CPUE) were all significantly lower at Tanga and Mtwara compared to Mafia indicating that the former sites may be overfished. Abundance of smaller individuals was higher at Tanga and Mtwara, but overall biomass was lower. Octopi at each site exhibited allometric growth as indicated by analyses of the length-weight relationships. Females become sexually mature at a minimum weight of 600 g while for males the minimum weight was 320 g. Higher numbers of mature individuals were found in June of both years and correlate with peaks in the gonosomatic index. Recruitment peaked a few months after brooding periods. Sex ratios indicate females may be more prone to capture during brooding periods. Reasons for differences between sites are discussed.

INTRODUCTION

Artisanal fishing for octopus is a highly important economic and subsistent activity for local coastal communities in the East African region and is extensively practised along the coast of Tanzania (1, 2). Yet, despite its importance little information is available on the ecology and life cycles of fished octopus species (especially *Octopus cyanea* Gray 1849) in East African tropical waters, levels of fishing intensity and possible implications for fisheries management. In fact, the majority of studies initiated in Africa have been conducted in temperate or subtropical waters and concentrated on octopus biology (3) or trawl fisheries (4) and not on traditional 'small scale' fisheries as practized in Tanzania.

Octopi, named *pweza* in Kiswahili are collected from intertidal reef flats and subtidal inner reefs for both local and inland consumption and for export to European and Far Eastern markets (2). Octopus are collected either by walking over the lower reaches of the intertidal reef flat or by snorkelling along the reef edge where they live in small holes (dens) and crevices often hidden by small stones, rubble and pieces of shell. Once spotted a slender stick or metal spear is inserted into the den and jerked up and down, thus causing the octopus to grasp the stick. It is then withdrawn and either immediately turned inside out to remove the heart, or the spear is pushed through the beak into the brain to kill the animal.

Traditionally, fishing for octopus has been dominated by women and children and is important for being one of the few sources of income for this gender group. In recent years, however, men have become increasingly involved with octopi fisheries due to a rise in demand and greater income opportunities (5). Outside buyers, who export octopus, now operate along the coast, and using specially commissioned boats to take fishers to fishing sites also pay premium prices for the catch. While providing much needed income to local communities, fishing intensity has markedly risen, placing greater pressures on the fishery.

To address these issues a collaborative study of the artisanal octopi fisheries in Tanzania was initiated in April 2000 between the University of Dar es Salaam, Tanzania and the University of Aberdeen, Scotland. The main aim of the study is to support the development of realistic and effective management for octopi fisheries in the country through the provision of information relating to octopus biology, fishing impacts, and social importance and dependence on the fishery. The study is conducted over a 2-yr period at 3 research stations along the coast: Kwale Village, Tanga; the Mafia Island Marine Park; and Msamgamkuu Village in the newly gazetted Mnazi Bay Marine Park, Mtwara.

The study has 6 key objectives:

- train and utilize fishers to collect octopi catch and effort data from comparable sites;
- determine ecology and life-history characteristics for *Octopus cyanea*;
- determine the impact and effects of fishing on local octopi stocks through analysis of catch and life history data and applied experiments;
- identify socioeconomic importance and dependence;
- develop a database of octopi fisheries catch and research data;
- describe the octopus fauna of Tanzania.

This paper provides preliminary results of catch data for Mafia, Tanga, and Mtwara for the first 15 months of the study and results of reproductive biology for Mafia Island. Implications for management are discussed.

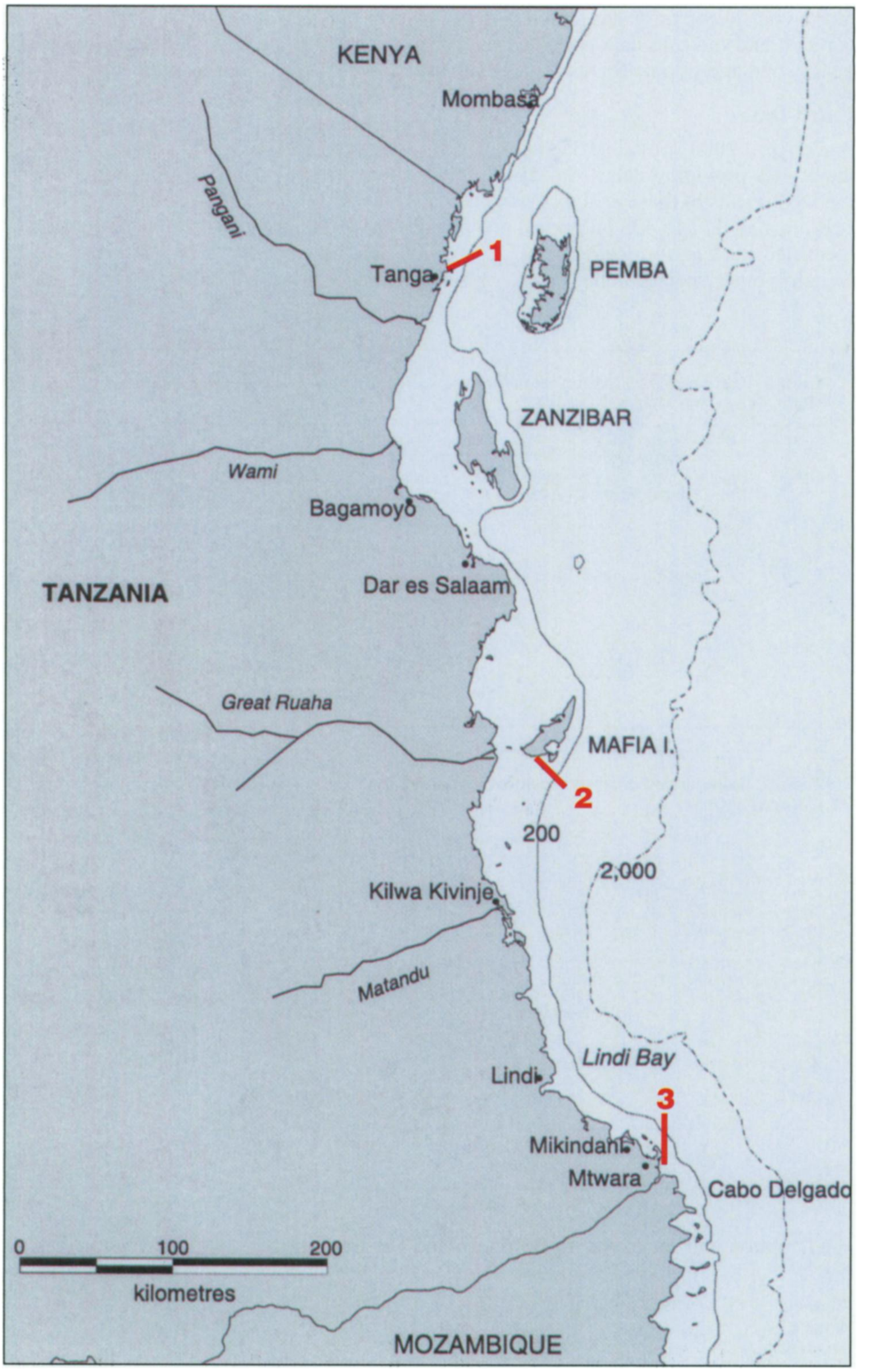
MATERIALS AND METHODS

Three sites were chosen for this study; Kwale Village in Tanga, Jibondo Village in the Mafia Island Marine Park, and Msamgamkuu Village in Mtwara (Fig. 1). Sites were chosen to represent 3 separate geographical areas along the Tanzanian coast namely the north, central, and southern areas and for their similar physical and environmental character. All fishing activity for octopus at these sites occurs on adjacent coral reefs within the intertidal and inner subtidal zones.

Catch and effort data from each sampling site were collected by a team of 3 fishers after selection and training in the recording and measuring procedure for a period of 3 days. Two team members are responsible for identifying the species, weighing, measuring, and sexing the octopus and the third member of the team assigned as supervisor records the data onto specially designed data forms. The supervisor also collects time records of fishing activity and has additionally trained in the removal and preservation of gonad material for later analyses. A maximum of 50 gonads are collected per site per spring tide (sampling period). The data collection methods used in this study were designed to provide maximum information for fisheries assessment while being simple enough for local fishers to learn quickly and continue with minimal supervision. The following components are recorded.

- Time of departure from landing site;
- Time of arrival at fishing site;
- Name of fishing site;
- Time of return to landing site;
- Length of time spent fishing;

Figure 1. Map of Tanzania indicating the positions of the 3 study sites namely: Tanga, Mafia Island and Mtwara.



- Fishing zone (intertidal or subtidal);
- Weight of each octopus in the catch (to the nearest 20 g);
- Dorsal mantle length (to the nearest cm);
- Total length (cm);
- Species;
- Sex.

All catch and gonad data were entered into an Access database and analyzed using Access, Excel and SPSS to provide results for catch yields, average weight by month, weight frequencies, catch per unit effort (CPUE), recruitment and sex ratio. Average weight by month, and CPUE were tested for differences using 1-way ANOVA and a Bonferroni post *hoc test*. Prior to analyses, variance of the means was tested using Levene's test for homogeneity. Weight frequencies were analyzed using a nonparametric Kruskall-Wallis test as data did not fulfil assumptions for parametric statistical analysis.

Length-weight relationships were examined using the power curve equation:

$W = qL^b$ (6)

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.

Sexual maturity was determined on a 5-stage maturity scale for females and 3-stage maturity for males (7 with minor modifications). A gonosomatic index was 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 were of the highest quality, validation tests were repeatedly conducted through the sampling period. Validation tests involved the comparison of measurements from 30 octopi per test between the recording team and the field coordinator, an experienced fisheries scientist. The results were tested using an independent t-test and Pearson's correlation coefficient. Prior to analysis the results for weight, dorsal mantle length and total length were tested for normality using a Kolmogorov-Smirnov test.

RESULTS

Validation Tests

Results of the validation tests for each location are given in Table 1. For each category tested, no significant differences were found for all t-tests between the recording team and the field coordinator at each site. Similarly, the results of Pearson's correlation coefficient provided significant association between recorders, and indicate data collected by fishers to be of a high quality and appropriate for statistical analysis.

Catch Data

Since April 2000, a total of 358 sample days were recorded for the 3 sites providing data from 2546 individual catches. Summarized results of these analyses are given in Table 2.

From a total of 15 473 individual octopi analyzed 99.9% were identified as *Octopus cyanea* Gray (1849) with, only very occasionally, other species being taken. *Octopus cyanea* known as the day octopus was easily identified from 2 ocelli located a few centimeters below the eye, elliptical white spots found on the dorsal side of the arms and zebra stripes or bands on the ventral arm face (8). Males were differentiated from females by the presence of a ligula found at the end of the hectocotylized arm (3rd right arm).

Collection intensity of octopus and fishing regimes varied between sites. Fishing intensity was highest at Mafia Island with up to 70 fishers km^{-2}, and which was more than twice the intensity of Tanga and approximately 1.5 times the intensity of Mtwara (Table 2). Fishing at Mafia, however, is conducted on

Table 1. Results of 3 validation tests for data collectors at Mafia, Tanga and Mtwara.

Location	Category	t-test	Sig	R	Sig
Mafia	Weight	–.028	ns	0.999	P < 0.01
	Dorsal mantle length	–.849	ns	0.948	P < 0.01
	Length	.966	ns	0.966	P < 0.01
	Sex	.236	ns	0.719	P < 0.01
Tanga	Weight	.182	ns	0.986	P < 0.01
	Dorsal mantle length	.691	ns	0.940	P < 0.01
	Length	.485	ns	0.977	P < 0.01
	Sex	–.349	ns	0.941	P < 0.01
Mtwara	Weight	–.024	ns	0.999	P < 0.01
	Dorsal mantle length	.081	ns	0.994	P < 0.01
	Length	.000	ns	1.00	P < 0.01
	Sex	-.183	ns	0.969	P < 0.01

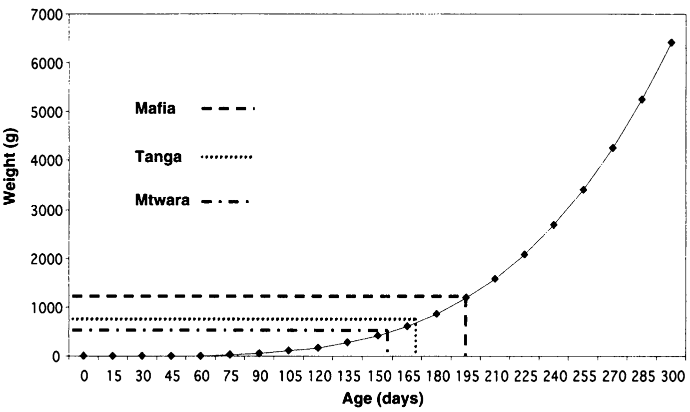
Table 2. Summarized data for the artisanal fishery for *Octopus cyanea*.

	Tanga	Mafia	Mtwara
Area sampled km^2	16	30	12
Fishing intensity km^{-2}	5.5	9	6
Total yield mt yr^{-1}	120	400	25
Economic value TZ Shillings x 10^6)	48	160	10
Avg. catch per trip	5257	6463	3123
CUPE kg man^{-1} hr^{-1}	1385	1719	808
Avg. size (g)	643	1192	478
Max (g)	4100 unknown	11 700 male	4940 female
Min (g)	20	100	60
Avg. no. per catch	8.1	5.4	6.7
Fish processor	Yes	Yes	No
Size limit	No	Yes	No

Table 3. Fishing regime for *O. cyanea* at Mafia, Tanga and Mtwara.

	Tanga	Mafia	Mtwara
Type of fishing regime	Repeated	Rotational	Repeated
Avg no. days fished per spring tide	7	Max 2	5
Relaxation period between springs tides (days)	4/5	10/13	7/9
Mean reduction in the no. of relaxation days compared to Mafia	6–8 days	–	3–4 days

Figure 3. Growth curve and estimated age of *O. cyanea* for each location (based on (9)).



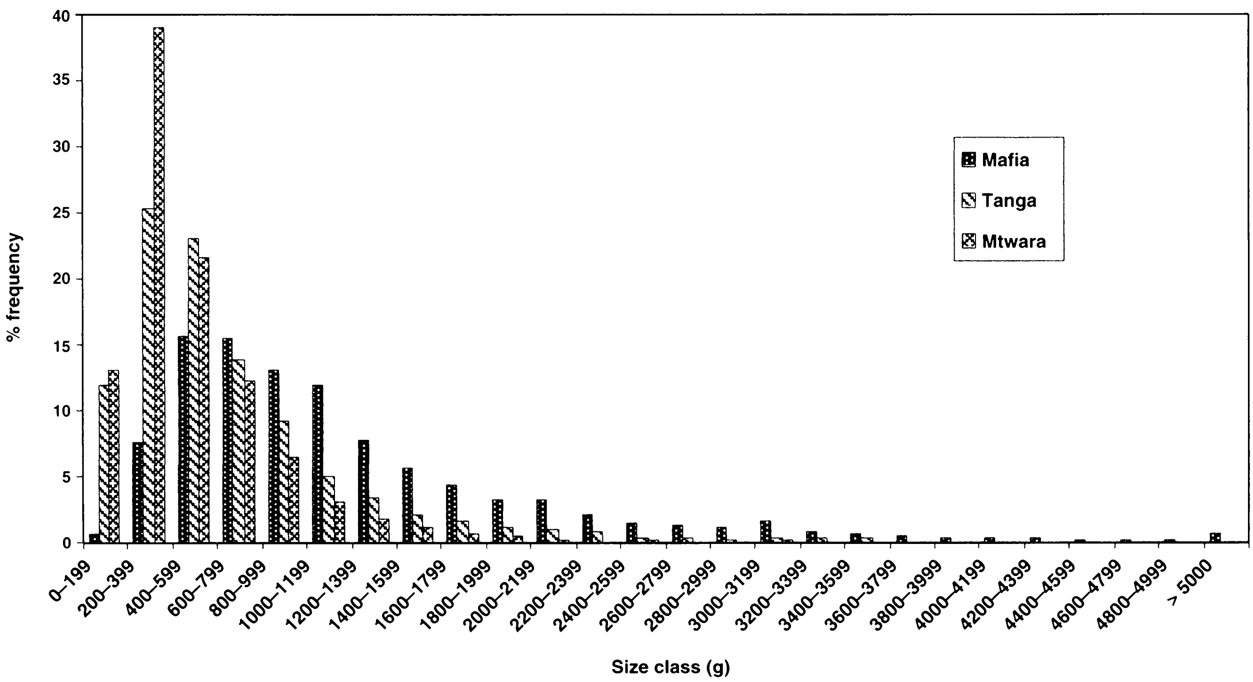
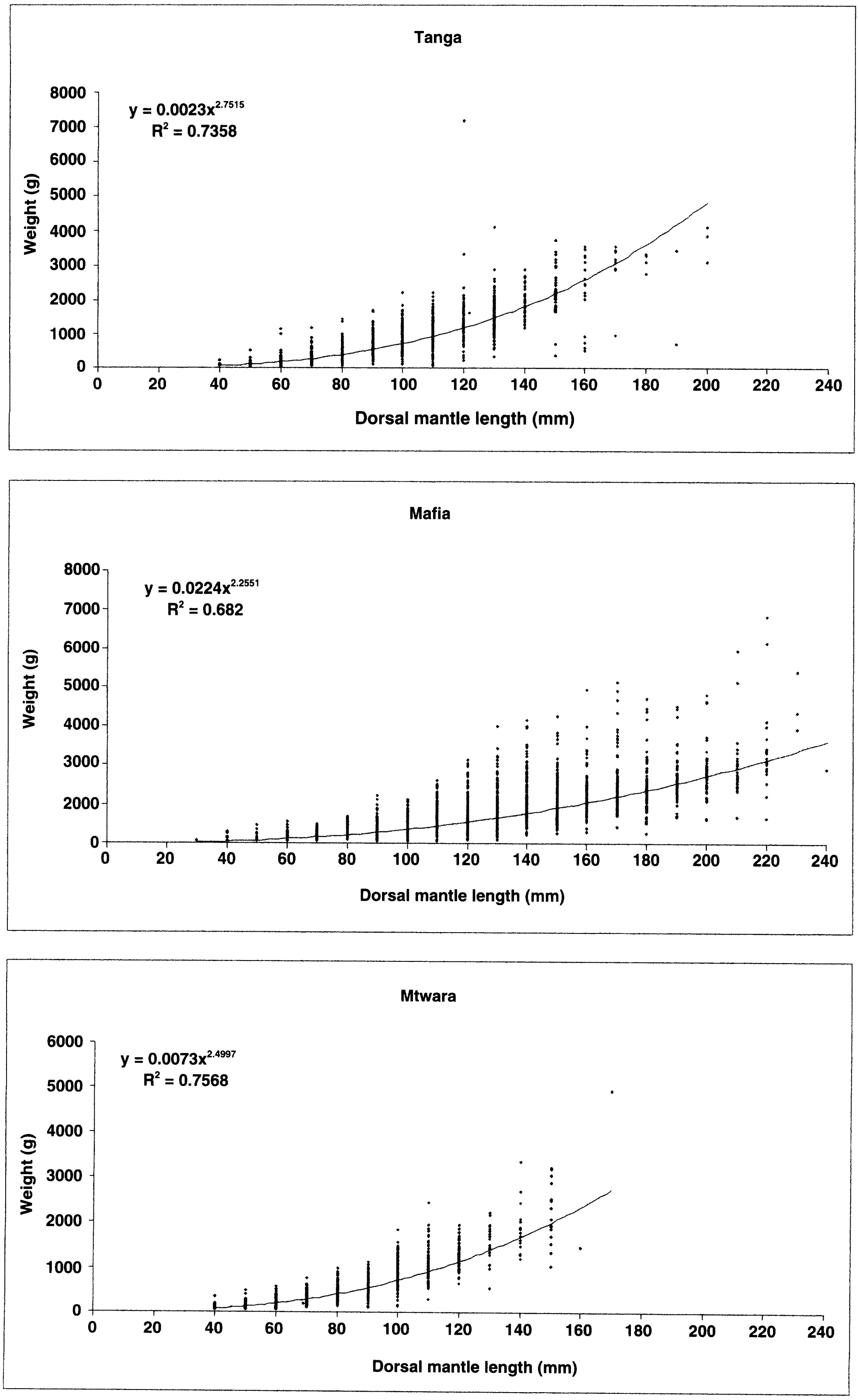


Figure 2. Weight frequency distribution of *O. cyanea* for each location.

a rotational basis at different reef sites during the spring tide whereas at Tanga and Mtwara fishing for octopus is repeated over a single fishing area. Table 3 indicates the average number of days each reef site is fished and the average relaxation period between fishing events. This indicates that overall fishing intensity per spring tide is actually higher at Tanga and Mtwara than for Mafia. This finding is reflected in the results for total catch yields, average weight of octopi, and catch per unit effort (CPUE) all of which were significantly lower at Tanga and Mtwara compared to Mafia, and especially marked for Mtwara. In contrast, higher numbers of octopus were taken per catch at Tanga (average 2.7 more per catch) and Mtwara (average 1.3 more per catch) compared to Mafia although on average a far smaller size. At Tanga, octopus less than 100 g and as small as 20 g are regularly taken by fishers and contributed 3.1% of the catch. The octopus processor at Tanga actively buys smaller octopus in order to supply a specific market in Europe, which favors smaller sizes. This practice may encourage the taking of undersize/immature octopi which may otherwise be left especially if they could not be sold. No octopi less than 100 g were taken from Mafia where the processor operates a minimum size limit of 500 g. The largest catch taken was from Mafia, weighing 46.4 kg and consisting of 11 octopi. The largest individual octopus caught weighed 11.7 kg with a total length of 1.58 m.

Figure 4. Length weight relationships for *Octopus cyanea* at each location.



The total economic value of the octopus fishery based on 300 Tanzania Shilling (40 US cents) paid to local fishers amounts to approximately 218 million Tanzanian Shillings (USD 245 000) for the 3 locations (Table 2). This figure is a substantial and important input to the local economy at each site especially for Mafia and Tanga. Octopus processors are operating at these locations but not at Mtwara. Considering the total does not include catch yields taken from the Songo Songo Archipelago or the Zanzibar Islands the national importance of this fishery is clear.

Examining the weight frequencies of octopi between sites (Fig. 2) it is clear that Mafia has significantly more octopus of larger size (Kruskall-Wallis test: Chi-squared = 17.006, $P < 0.001$). Over 36% of octopi at Mafia were over 1200 g compared to 12% at Tanga and only 5% at Mtwara. Over 7% of octopus taken at Mafia were over 5 kg with no octopus reaching this weight at the other 2 sites.

Figure 3 provides an estimate of age for the average size of octopus at each location using the growth curve for *O. cyanea* by Van Heukelem (9). For Mafia the average age of octopus is approximately 200 days while for Tanga and Mtwara is approximately 173 and 160 days, respectively. The difference of 27 days and 40 days for Tanga and Mtwara compared to Mafia may seem small but considering *O. cyanea* has a maximum lifespan of 400 days (9) this difference represents a 7 to 10% increase in age. Moreover, 36% of the catch at Mafia are larger than 1200 g and 7% of the catch over 5 kg would be in excess of 270 days equivalent to a 24 to 28% increase in age compared to average size of octopi for Tanga and Mtwara.

Results of the length-weight analyses for each site are given in Figure 4 and indicate that all octopi exhibited allometric growth. When comparing 2 exponents the animal with the higher slope value (b) is increasing in weight per unit increase in length at a faster rate than the animal with the lower slope value. Octopi at Tanga are therefore indicated to grow at a faster rate than the octopi of Mtwara which in turn are indicated to grow at a faster rate than the octopi of Mafia.

Examining average weight of octopi for each month by location (Fig. 5) it is clear that Mafia octopi are significantly larger all year round ($F2,82 = 82.617$; $P < 0.001$) than the other 2 sites. The largest average size of 1.76 kg was recorded for Mafia in June compared to 926 g for Tanga in September and 615 g for Mtwara in November. Noticeable are 2 marked peaks followed by sharp declines in average weight in June/July 2000 and June 2001 for the Mafia data set. These peaks followed by declines may represent groups of cohorts reaching maximum size at the end of their lifespan when both males and females die after brooding activity causing a reduction of large individuals in the population. Peaks in average weight for Tanga and Mtwara are less pronounced. For Tanga, September/October may represent a peak followed by a decline and to a lesser extent in November at Mtwara, yet it is clear they do not follow the same pattern as Mafia. Overall there is a basic trend of declining average weight over the sampling period for each location.

Catch per unit effort (CPUE) was significantly higher at Mafia ($F_{2,32} = 22.672$, $P < 0.001$) for the majority of the sampling period (all months for Mtwara) except for April and May when CPUE at Tanga is markedly higher than Mafia and Mtwara (Fig.

Figure 5. Average weight of *O. cyanea* by month and location.

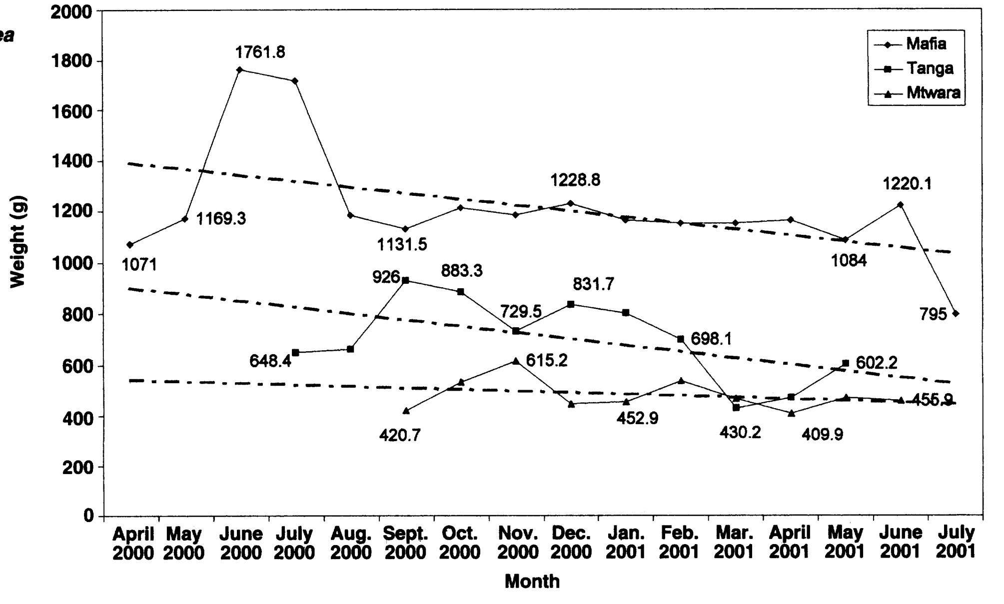
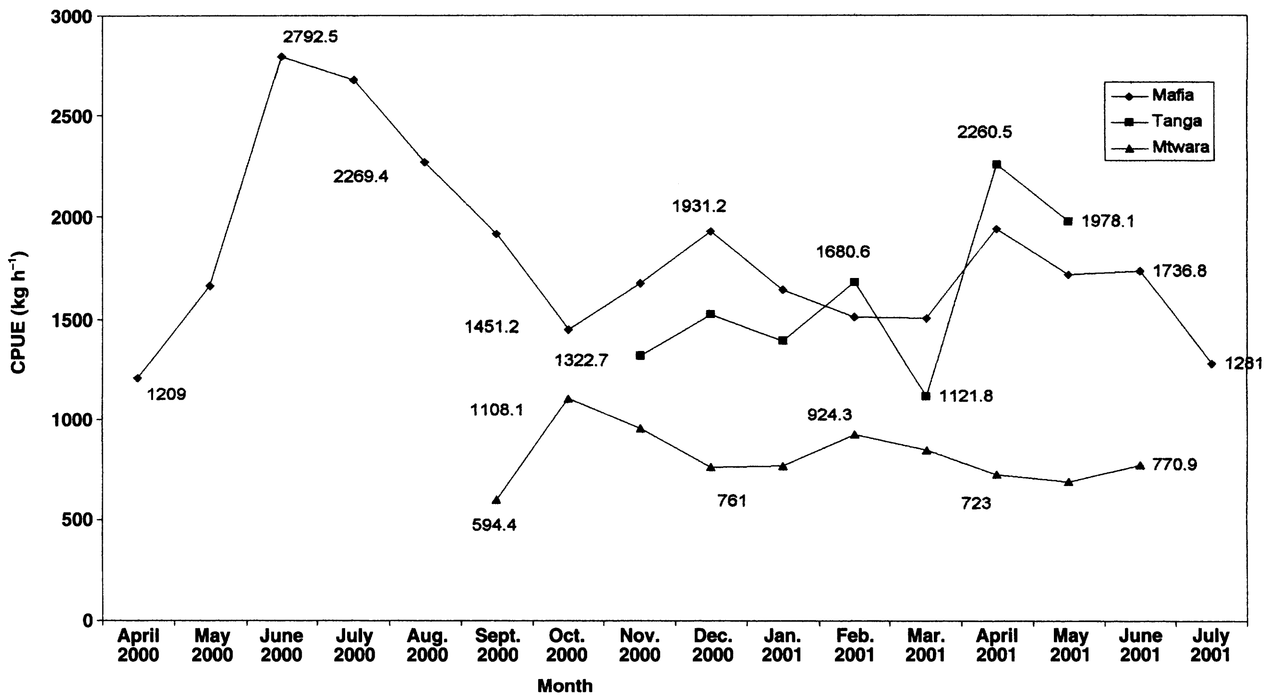


Figure 6. Catch per unit effort for *O. cyanea* by month and location.



6). The highest CPUE at Mafia was 2.8 kg compared to 2.3 kg for Tanga and 1.1 kg for Mtwara. On average CPUE is 2 to 3 times higher at Mafia than Mtwara and the lowest CPUE from the former is over 170 g higher than the highest CPUE from Mtwara. At Mafia the peak for June/July 2000 clearly agrees with the peak observed for average weight but other CPUE peak/declines for December and April/June 2001 also tentatively agree. The reason for the marked peak at Tanga in April is not absolutely clear although average weight of octopi does concurrently increase during this period, but is not as marked as for the Mafia peaks. No zero catches were recorded for Mafia or Tanga during the sampling period with fishers claiming to have caught at least 1 octopus. At Mtwara, zero catches are occasionally evident but are not included in the CPUE calculations for this site. CPUE for Mtwara may therefore be overestimated and highlights further the difference between this site and those on Mafia. For Mafia and Mtwara there is evidence of declining CPUE through the sampling period although less pronounced for the latter location. In contrast, Tanga CPUE increased through the sampling period.

Reproductive Biology

Results of gonad analyses are given for the combined sites of Mafia only, extending from April 2000 to June 2001. A total of 334 males were examined and 80% were classed as mature (Stage II of 3-point maturity scale). The smallest Stage II mature male weighed 320 g. The largest mature male undergoing gonad analysis weighed 5.4 kg, but the largest male caught from Mafia weighed 8.8 kg.

Out of a total of 367 females examined only 4.9% (n = 18) were classed as mature (Stage IV of 5-point maturity scale) and ready to produce and brood eggs. The maximum number of 4 mature females in one month was recorded in June and represented just 14% of the total number of females analyzed for that month. The smallest mature female ready to spawn weighed 600 g, but 15 of the 18 mature females weighed above 2500 g. The largest mature female examined weighed 8050 g, but the largest female recorded from Mafia weighed 11.7 kg. The frequency of maturity (based on a 5-point maturity scale) for females is given in Figure 7. Higher numbers of Stage IV individuals are noted for both June 2000 and June 2001 indicating heightened brooding activity. In contrast, the highest number of stage I females are found in September and March/April 2001 but the most pronounced increases in Stage I females appear in July and January, which follow on from the peaks evident for average weight and CPUE. Stage IV females were found in 10 out of the 15 months suggesting brooding may occur throughout the year, but with brooding peaks in certain months.

Results of the gonosomatic index for males and females at Mafia (Fig. 8) indicate a corresponding pattern of activity for both sexes with several clear peaks evident. For females a marked peak is observed for the month of June in both years and in the former is followed by a sharp decline in the index. Less significant peaks are seen in September and January. For males the index indicates a high level of mature individuals throughout the period except for July and April when declines are noted. Although low numbers of Stage IV females were encountered during gonad analyses the index will be sensitive to increases or decreases in other maturity stages such that an increase in Stage III females may cause a peak. Furthermore, the GSI for females indicate declines during the same months as a marked increase in Stage I females in Figure 7 and after peaks in average weight and CPUE for Mafia.

Sex ratios for each month indicate a marked dominance of females during June and July and to a lesser extent in December of the first year (Fig. 9). Outside of this period sex ratios are near to unity. The dominance of females during June, July and December corresponds to peaks in the gonosomatic index, which also agree with increased average weight and CPUE for these periods. This agreement may indicate brooding females are more prone to capture during these periods.

Recruitment

Results for recruitment based on length frequency data (Fig. 10) provided 2 periods of recruitment, a larger pulse during September and a second smaller pulse during February. If we assume

Figure 7. Percentage frequency of maturity for female *O. cyanea* at Mafia.

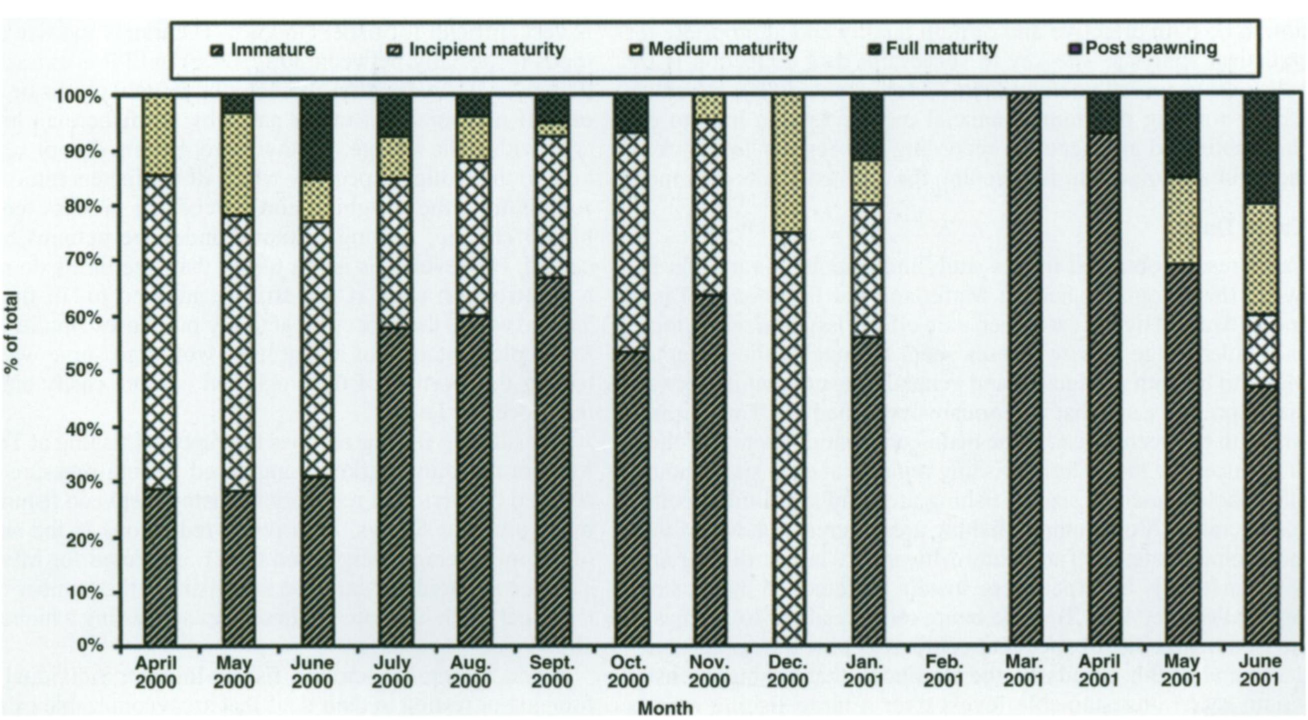
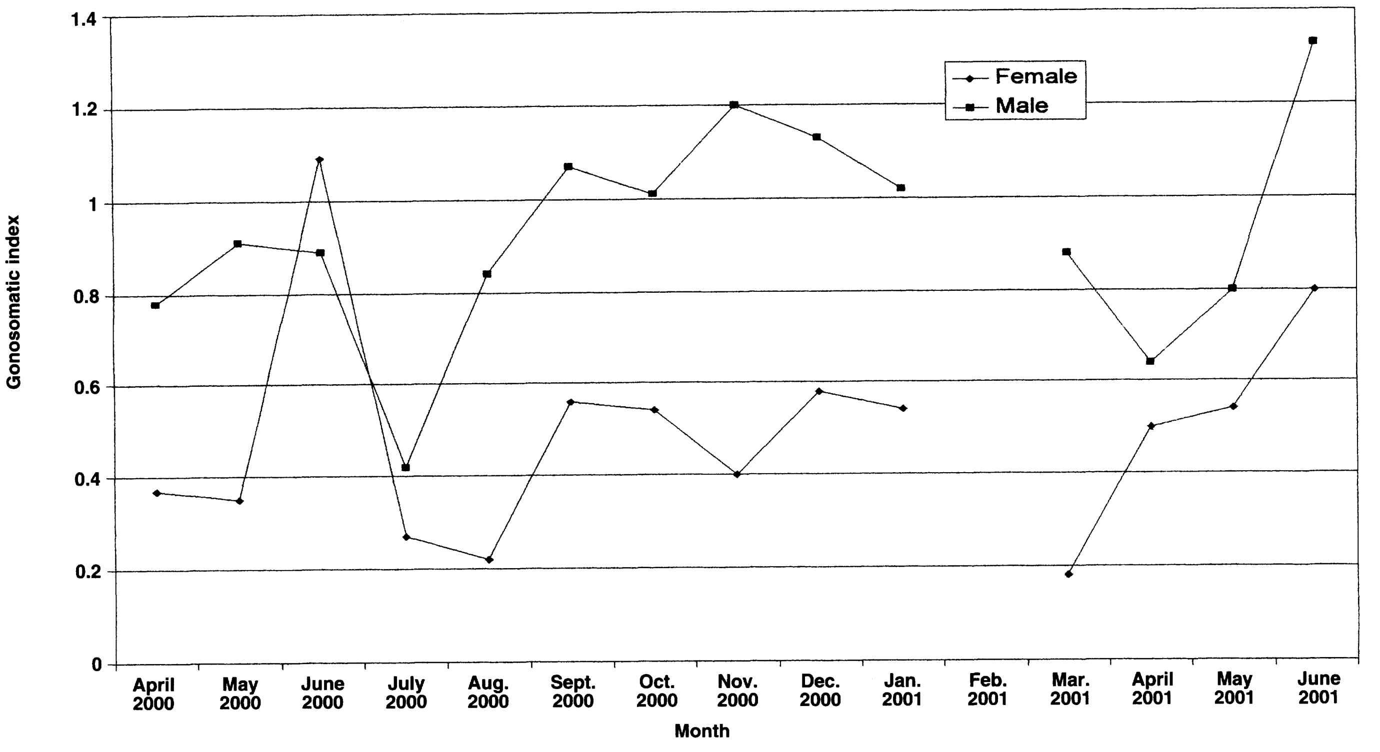


Figure 8. Gonosomatic index for males and female *O. cyanea* by from Mafia by month.



that brooding of eggs to hatching takes approximately 20 days (9) and newly hatched larvae enter the plankton in June for a period of 30 days (10) this would leave between 90–105 days post-settlement to grow to recruitment size. Using the growth curve (Fig. 3) by Van Heukeulem (9) we can tentatively surmise that recruiting individuals in September would weigh a minimum of 50 to 105 g and for the month of October would weigh between 105 to 175 g.

DISCUSSION

Validation Studies

The validation test results in this study indicate the data collection to be both effective and of high quality and appropriate for statistical analysis. The key to successful data collection is for assistants to record no more than 3 components following an effective training program. Financial incentives also help to ensure motivated and accurate recording and regular feedback of the results is important for keeping the data assistants informed.

Catch Data

Catch results obtained in this study indicate great variation between the octopus fishery at Mafia and the fisheries of Tanga and Mtwara. Higher catch per unit effort, larger sized octopus and wider range of size classes seem to suggest the fishery at Mafia to be both productive and generally healthy while Mtwara may represent a site that is seriously overfished and Tanga somewhere in between. Clearly, the main contributing factor for these differences are the differing fishing regimes at each site although other factors such as size of fishing area and size limits require consideration. For example, fishing area is greater at Mafia than the sampled sites at Tanga and Mtwara. A larger fishing area would naturally be expected to sustain more octopi than a similar smaller site (11, 12) while being more resilient to stochastic environmental disturbance that could affect local octopus abundance and health. Similarly, the likelihood that fishing intensity would reach unsustainable levels over a large fishing area is greatly reduced, although certainly could happen. In contrast, at smaller reef sites such as Tanga, fishing pressure could become unsustainable even at a low fishing intensity and fishers repeatedly visiting this site would have a greater degree of memory recollection of the fishing area and could probably even remember particular den sites. Size of fishing area could also influence recruitment success (13) and as octopi have an initial planktonic stage the shallow water plateau and outer reef complex at Mafia may benefit from higher plankton to benthic settlement both from within and outside of the area.

Another factor, which may contribute to these differences is the 500 g size limit imposed by the processor at Mafia for the purpose of reducing off-take of immature octopus. In reality, however, the effectiveness of the size limit is ambiguous, as it is very difficult for fishers to know accurately the size of an octopus (especially between 300–500 g) until it is extracted from its den. After extraction the octopus is unlikely to be returned even if undersize but rather eaten by the fisherman himself or sold within the village. Furthermore, buyers do not strictly adhere to this policy especially when all the fishers return at once. At this time the weighing and purchasing process tends to be highly chaotic, leading to many undersize octopus being accepted. However, this is not to say that size limits do not make a contribution even if not strictly adhered to. In the case of Tanga, where the processor actively purchases smaller octopus, the implementation of a size limit would go some way to protecting this portion of the stock and is more easily enforced at the processor level.

Considering fishing regimes the repeated fishing at Tanga and Mtwara not only markedly increased fishing pressure but also reduced the period of recovery for octopi between fishing events by as much as 8 days. As a result reductions in the size range of octopi, average weight and CPUE are noted for Mtwara and Tanga compared to Mafia yet surprisingly the number of octopi taken per catch is greater at these sites suggesting a higher overall abundance.

When fishing for octopus, fishers look for individual octopus foraging or resting in their dens that are recognizable by the coral

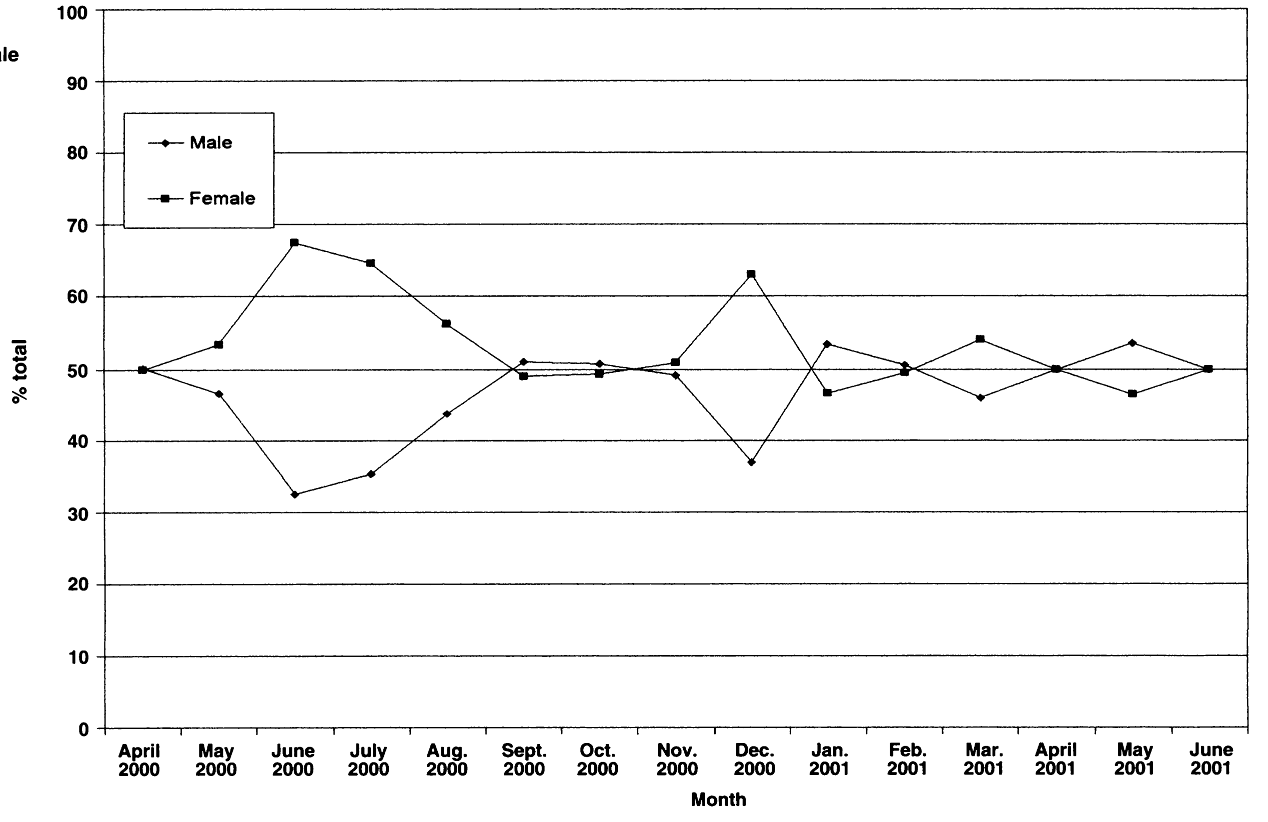


Figure 9. Sex ratio for male and female *O. cyanea* at Mafia by month.

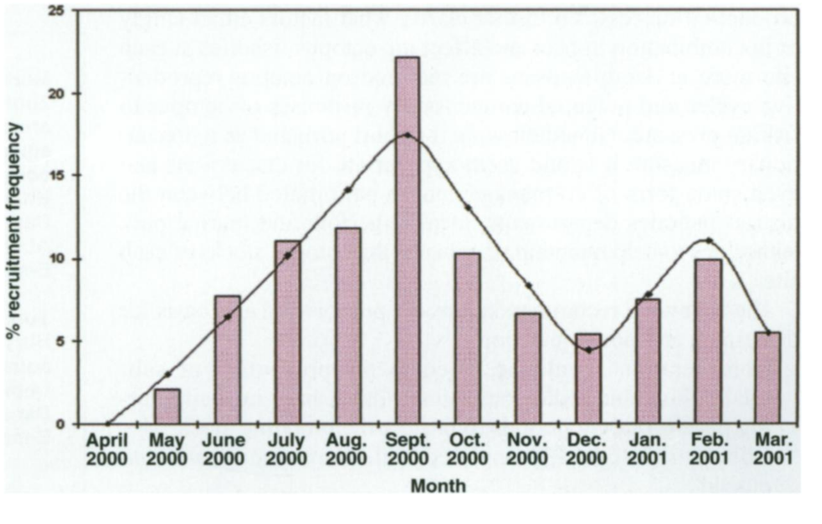
rubble placed at the entrance. Larger octopus or their den sites are easier to see than small octopus and large individuals have been shown to occupy den sites for longer periods (9, 11). Fishing activity would therefore be expected to select large size classes first and, depending on the level of fishing intensity, large size octopus are either capped at a particular weight or continue to decline in size. But why an increase in abundance? Basically, large octopi need a greater foraging area than smaller individuals to maintain their energy requirements (11). Thus, a reduction of large octopi would enable a higher density of smaller individuals for the same given food resource as reported for Mtwara and Tanga. Furthermore, Packard (14) and Van Heukelem (9) report that large octopi in aquaria will actively chase away and sometimes cannibalize smaller sized individuals. A reduction therefore may benefit smaller individuals through competition and predation release and the latter effect would be especially pronounced if other natural predators such as finfish were similarly reduced through overfishing. Abundance of octopus is also influenced by the availability of suitable dens and these would be expected to be more numerous for smaller individuals (7, 12).

In this study, declines in average weight are indicated for all sites over the sampling period but are far more significant for Mtwara and Tanga as the average weight and the size range of octopi are already markedly reduced when compared to Mafia. In addition, although abundance may be higher at the former sites due to a combination of competition and predation release, the overall biomass has dramatically declined as indicated by the lower overall figure for catch per unit effort at these sites.

Results of the length-weight relationships indicate that octopi at Tanga are increasing in weight per unit length at an overall faster rate than the octopi at Mtwara and Mafia and imply faster growth. Faster growth at the former sites may be explained by the progressive decline in growth rate with age during the logarithmic growth phase of adult octopi (15). Small individuals are more dominant at Tanga and Mtwara and may explain the faster growth reported as many may be juveniles and still be growing at an exponential rate. In contrast, at Mafia a large proportion of sampled octopi are of large size and probably naturally grow at a slower rate: hence the differences. What is clear from the graphs is that for mantle lengths above 120 mm there is a greater proportion of large individuals at Mafia than at the other 2 sites, indicating a slower growth rate but overall much higher biomass. Thus, the Mafia stock may be more valuable in terms of potential yield than Tanga or Mtwara assuming that market factors are equal.

Shifts in size and age distributions as reported here may also have profound effects on reproductive output (16). Female octopi brood only once in their lifetime and when ready, normally at the largest size, barricade their den, attach the eggs to the den

Figure 10. Recruitment of *O. cyanea* for Mafia from April 2000 to March 2001.



roof and then spend the next 30 or so days cleaning, aerating, and preventing predation of the eggs until they hatch (17). From this time onwards the female octopus does not feed and gains her energy requirements from the breakdown of somatic proteins (9). This process is irreversible so when the eggs eventually hatch a few days later the female dies. Thus, the females survival is integral to the success of the eggs and for management purposes it is essential to protect the reproductive stock through maintaining reproductive output and encouraging a reduction of fishing pressure during brooding peaks. As female octopi normally reach reproductive status at the largest size, marked reductions in the size range may seriously inhibit reproductive output leading to a reduction in recruitment and eventually stock size. At Mafia the smallest size of a mature female was 600 g with over 80% of mature females weighing over 2500 g. At Mtwara, the overall average weight is just 478 g with only 13% of females above 600 g and just 0.24% above 2500 g. Similarly at Tanga only 20% of females are above 600 g and 1.44% above 2500 g. These findings indicate that unless the octopus stocks at Tanga and Mtwara have gone through some form of compensatory adjustment to fishing pressure and brood at a smaller size, reproductive output at these sites may already be dramatically reduced. This assumption is now being investigated. It has also been shown that a population of a given biomass will have a higher relative fecundity when composed of larger rather than small individuals (9). For Tanga and Mtwara it may be assumed that not only are there less females reaching brooding status, but those that do, produce less eggs than at Mafia.

The peak brooding period for Mafia is indicated by an increase in mature individuals (Fig. 8) and a peak in the gonosomatic index (Fig. 9) for June and to a lesser extent in December. These peaks agree with peaks for average weight, and CPUE. Of concern however, is the dominance of females in the catch during the peak periods in 2000 suggesting that females are more prone to capture during this period. When females brood they completely barricade their dens with rubble and coral fragments and this may result in the den being more obvious to fishers. Results in Guard (5) indicate that large size octopi are found primarily in the subtidal zone and ideally this zone should be protected during brooding periods.

Results of recruitment analyses indicate a peak in September and a less intensive peak in February, and based on the growth of juvenile octopi (9), (see above) when back calculated, support the assumption of a June and December brooding period. Further analyses are nonetheless necessary to confirm these findings.

CONCLUSIONS

From the preliminary results provided in this paper it is apparent that overfishing of octopi may be occurring at Tanga and Mtwara with knock on effects on reproductive output and reproductive success. To further clarify what factors either singly or in combination impact and affect the octopus fisheries at each site more in-depth analyses are required on octopus reproductive cycles and potential compensatory responses of octopus to fishing pressure. Nonetheless, in the short term and as a precautionary measure it would seem appropriate for discussions and even some form of co-management to be initiated between the district fisheries departments, local fisherfolk and marine park authorities to help maintain or enhance the octopus stocks at each site.

The following recommendations are put forward as a basis for discussion and possible action.

- Consideration should be given to the prevention of subtidal fishing and reduction of intertidal fishing intensity during peak brooding periods to protect the brooding stock—localized trials could be initiated and alternative means discussed.
- Overfishing of octopi may be reduced if fishing is restricted for a maximum of 5 days over the spring tide with no fishing allowed during neap tides. This is the case at Mafia and catches are markedly higher.
- Catch monitoring should be implemented at each site to provide long-term data and to monitor the effectiveness of implemented actions.
- Minimum size limits of 500 g imposed by all processors would help to discourage the taking of small octopi.
- Manipulation studies should be conducted to assess further the impact of fishing on octopus stocks.

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