FINAL TECHNICAL REPORT

VILLAGE-BASED LARVICULTURE AND STOCK ENHANCEMENT OF SEA CUCUMBERS (ECHINODERMATA: HOLOTHUROIDEA) ON THE KENYAN COAST

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EXECUTIVE SUMMARY

Marine protected areas were initiated in Kenya for biodiversity conservation in marine parks and as fisheries management areas in marine reserves. Unfortunately overexploitation of marine resources in unprotected areas is beginning to erode the gains made by MPAs, creating an environment of conflict with marine parks that are no-take zones. In order to resolve this conflict, viable resource use alternatives have to be explored.

The holothurian fishery is a potentially very valuable fishery with characteristics that allow low income fishers to have gainful employment. However little is known about this fishery in Kenya. This study therefore investigates the status of the holothurian fishery in Kenya including the diversity and distribution of holothurians, the reproductive patterns of holothurians as a prelude to culture and stock enhancement trials, and identifies communities adjacent to MPAs that could participate in a pilot stock enhancement project for holothurians

This is the first set of data available on the holothurian resources of the Kenyan coast. Holothurians were distributed throughout the Kenyan coast from Kiunga in the north to Kisite in the south. A total of 31 species were recorded with one new species tentatively named *Holothuria arenacava* not previously described in the Western Indian Ocean (WIO). This is a relatively high diversity and is comparable to holothurian diversity in other locations in the WIO region. The most common species was *H. atra* and *H. leucospilota* which are also common in the WIO region. Seventeen species were of commercial value including the high value species *H. fuscogilva*, *H. nobilis* and *H. scabra*. Sandy channels and hard substrate channels had the highest abundance of holothurians (5 – 15 individuals/250m^2) and seagrass areas the lowest (2 individuals/250m^2).

The reproductive patterns of two high value species *H. fuscogilva* and *H. scabra* and the new species *H. arenacava* were investigated. *H. fuscogilva* had a relatively short spawning period between October and December. Peak spawning occurred during the hottest months of the year although there was no correlation between spawning and sea water temperature or light. *H. scabra* also exhibited a short spawning period between August and December. The reproductive pattern of *H.*

scabra also did not show a relationship with sea water temperature or light. The reproductive patterns of both these species are similar to records from New Caledonia.

Holothuria arenacava on the other hand, had a characteristic annual reproductive pattern with spawning occurring between September and March of the following year. By April spawning has ended and gametogenesis commences in July. This is the first time a seasonal reproductive pattern has been recorded on the East African coast. The reproductive pattern of *H. arenacava* had a significant correlation with sea water temperature and light. The correlation with light however was very strong (r = 0.96) suggesting that light is a controlling factor in the reproduction of this species. The species occurs most of the time buried in the sand so light could act as a powerful cue to induce spawning.

The socio-economic study revealed that the fisher communities of many villages in the south coast of Kenya are engaged in holothurian fishing concentrated between Gazi and Shimoni. The main occupation is fishing although farming is carried out on a subsistence basis. The community has a low level of education and are classified in the low income group. The community depends mainly on natural resources for food, fuel, building materials and medicines. The level of awareness of conservation and environmental issues was high which is not surprising as there are three protected areas, Shimba hills national reserve and Kisite-Mpunguti marine park and reserve and Diani-Chale marine reserve in the district. These communities were keen on the prospect of culture and stock enhancement of holothurians.

Unfortunately the results from rearing holothurians were not so encouraging. In most cases spawning was successful through thermal stimulation. Fertilisation trials for *H. atra* and were also successful. However rearing of the larval stages beyond the doliolaria stage proved more difficult. This was possibly due to the microalgal diet but also to logistical problems. A great deal more research in required before a viable pilot project can be initiated.

Compilation of fisheries statistic, interviews and perusal of old records in the National Archives reveals that this fishery is over exploited. Catches have been declining from a high of 90 metric tons to a low of less then 20 metric tons. Size frequencies of *H. fuscogilva* and *H. scabra* collected from the catch indicate that a sizeable portion of the catch is sexually immature. Interviews with fishers have also indicated that large high value species are becoming more difficult to collect and the catch is increasingly dominated by mid value and low value species. All these indicate that the fishery is in urgent need of intervention.

We have provided information from this study to the fisheries department and an initial management intervention has been instituted requiring all District Fisheries officers to stop licensing any traders and collectors. We have further recommended a moratorium in marine reserves where enforcement would be more effective. This could be carried out for a period of three years with a monitoring program to record recovery. We have also recommended a comprehensive monitoring program that requires reporting on species, sizes and effort. This information will be key in developing effective management interventions for this potentially valuable fishery.

1 INTRODUCTION

1.1 Background

The coral reefs, seagrass beds and mangroves ecosystems of the Kenyan coast support an important finfish and shellfish fishery, play a key role in shoreline protection and sediment catchment, and directly or indirectly support coastal tourism the major foreign exchange earner in Kenya. However all these habitats are becoming increasingly degraded due to human impacts especially overexploitation. A rapid increase in the coastal population coupled with rapid development of coastal tourism has put a great deal of pressure on coastal resources (McClanahan and Obura, 1994). Over fishing for example has led to the loss of biodiversity and detrimental changes in community structure. On exploited Kenyan reefs, an explosion in sea urchin populations has occurred due to a drastic reduction in their finfish predators and competitors (McClanahan and Muthiga 1988: McClanahan and Shafir 1990). The detrimental effects of sea urchins on reefs has negatively impacted on shoreline protection and fisheries. Mangrove ecosystems are also seriously threatened with a total ban being recently implemented in Kenya.

The problems of marine resource exploitation on the Kenyan coast has partially been addressed by the Kenya Wildlife Service (KWS) by gazettement of Marine Protected Areas. Kenya currently has 4 marine parks managed as no take areas and 6 marine reserves where traditional fishing methods are allowed (Muthiga 1997). The use of protected areas has proven successful in the management of fisheries and preservation of biodiversity in many parts of the world (Bohnsack 1990: Roberts and Polunin 1991; McClanahan 1994) and Kenya is no exception. There is a higher diversity and abundance of key species in marine protected areas in Kenya than outside indicating the importance of these areas as refugia and supply of larvae to adjacent fished areas (McClanahan 1996).

Unfortunately, despite the proven potential of protected areas in biodiversity conservation, and fisheries, conflicts between the fishing community and MPAs have not been completely eliminated. Kenya's MPAs are perceived as mainly benefiting the tourism sector by the local fishing communities, whose fishing grounds were excised during creation of MPAs. This has led increasingly to non-compliance of MPA regulations and infringement of MPA boundaries by fishers resulting in an increase in the management costs of MPAs. Kenya Wildlife Service has addressed this issue through development of a Community Program that identifies key conflict areas and encourages the development of enterprises that allow communities adjacent to protected areas to benefit from conservation activities. In 1995, the Community Program of KWS carried out a profiling study of coastal communities adjacent to the Kisite/Mpunguti marine park and reserve (Mwadzaya et al 1995). The study identified that coastal communities have few opportunities to develop low-cost enterprises for generating income on a sustainable basis. A lack of alternative marine resource use was identified as an important issue and KWS took on the task of identifying areas of alternate resource use that could be explored as a potential project for fisher communities.

The sea cucumber fishery a potentially highly valuable fishery was identified as a potential alternative marine resource use. Although the sea cucumber fishery has existed in Kenya since the early 1900s, no systematic review of this fishery has been carried out. The sea cucumber fishery has features that enable the development of a viable community enterprise including the sedentary and conspicuous nature of sea cucumbers, the high value of the product, the low cost of processing and storage and the huge international market. This study was therefore developed primarily to collect and collate relevant information in order to explore the feasibility of developing a community based sea cucumber project for communities adjacent to MPAs in Kenya.

1.2 Aims and Objectives of the Study

Sea cucumbers have been harvested world-wide for thousands of years. The fishery is mainly dominated by the Pacific and Indian Ocean fishery with export mainly to the far east and China. Sea cucumbers are mainly consumed raw, boiled and pickled however the dried body wall (beche-de-mer, trepang or hoi-som) are the most important products (Conand 1989). Sea cucumbers have been harvested in Kenya since the 1930s but the collection of fisheries statistics of this fishery is poorly recorded (District report 1930). The usual fisheries statistics including catch statistics, catch effort and CPUE records are not available making it difficult to assess the trends in the fishery.

Additionally information on available stocks and ecological and biological information as well as socio-economic information that are key to managing a fishery or for assessing the feasibility of aquaculture are not available. The specific objectives of this study therefore are:

- To map the distribution and carry out a stock assessment of sea cucumbers along the Kenyan coast with a view of identifying sea cucumber species of economic value, their biomass and distribution as well as recording the diversity of sea cucumbers on the Kenyan coast
- To carry out studies on the reproductive patterns of species identified to be of economic value with a view of selecting those species with reproductive patterns conducive to the sustainable production of juveniles for culture or stock enhancement
- Develop and test different methods of larval production in the laboratory using several sea cucumber species with a view of developing simple and cost effective methods for the production of juveniles
- Carry out a socio-economic assessment of local communities and the feasibility of implementing a village-based aquaculture pilot project
- Gather comprehensive information about the sea cucumber fishery including the methods of collection and processing, the communities who are involved, legislative issues, trade and export.

2 STUDY AREA

2.1 Introduction

The Kenyan coastline is approximately 500 km long, with a well developed fringing reef system except where major rivers (Tana and Athi Sabaki) discharge into the Indian Ocean (Hamilton and Brakel, 1984). Patch reefs occur in Malindi and Kiunga in the north and Shimoni in the south on the Kenya Tanzania border. Coral reefs are the predominant marine ecosystem in terms of ecology and economy but seagrass beds and mangrove forests also contribute to the economy of the coastal communities. Seagrass beds are usually associated with reefs growing in the shallow lagoons between the shore and reef lagoons as well as in the shallow bays Ungwana and in the shallow channels of drowned river beds (Mtwapa and Kilifi creeks).

Mangrove forests are well developed in the Lamu archipelago where 70% of the total mangrove cover of Kenya occurs, and line the major creeks and estuaries including Kilifi, and Gazi. Coral reefs are poorly developed towards the north due to the influence of the cool waters from the Somali upwelling system. In general, the coral communities are similar to other parts of the Western Indian Ocean (Hamilton and Brakel, 1984) dominated by Porites assemblages in calm waters and Acropora assemblages in high energy waters.

2.2 Seasonality of the Kenyan coast

The climate and oceanographic conditions of East Africa follow a monsoonal cycle driven by the north-south migration of the Inter-Tropical Convergence Zone (ITCZ). Two main seasons, the north-east monsoon (NEM) and the south-east monsoons (SEM) occur along this coast characterised by marked differences in physical and oceanographic conditions (Fig. 2.1). During the NEM (October to March), winds are light, temperatures are warmer, therefore productivity is higher and benthic algal biomass is lower than during the SEM (Bryceson 1982; McClanahan 1988). During the SEM (April – September), conditions are opposite with high winds, lowered temperatures, reduced pytoplankton and zooplankton abundance and higher benthic algal biomass. These factors have a strong influence on coastal communities as well as on the reproduction of marine invertebrates.

3 HOLOTHURIAN DIVERSITY AND DISTRIBUTION

3.1 Introduction

Currently no information on the sea cucumber resources of Kenya, their distribution and abundance is available. In order to assess the overall diversity of sea cucumber resources on the Kenyan coast, surveys were carried out along the entire coastline in all five coastal districts from Lamu district in the north to Kwale district in the south (Fig 3.1). We collaborated with Yves Samyn of the Center of Ecology and Systematics, Free University of Brussels, Belgium for taxonomic verification.

3.2 Materials and methods

The distribution of sea cucumbers was surveyed in different habitats by snorkelling in shallow areas, walking on reef flats and shallow mangrove channels and SCUBA diving in deeper areas. An effort was made to survey as many different types of habitats as possible including mangroves, seagrass beds, sandy and soft bottoms and reef habitats. All sea cucumbers observed in the surveys were recorded on an underwater slate if easily identified in the field, or collected for later taxonomic verification as described below. Habitat characteristics of each species were recorded including depth, benthic substrate and other key features.

The abundance of sea cucumbers is usually very variable therefore several methods were used to assess the abundance of sea cucumbers along the Kenyan coast. In areas where sea cucumbers were sparsely populated, timed surveys (1 hour) were carried out by an observer either walking, snorkelling or SCUBA diving in a direction usually parallel to shore and observations were made as described above. Timed searches were repeated once at each site. At some sites within MPAs and outside MPAs two 100 m transects were laid on the substrate, an area 1.25m on either side of the transect (total of 250m^2 per transect) was surveyed by an observer either walking, snorkelling or using SCUBA. Sea cucumbers encountered along the transect were recorded as described above.

Sea cucumbers that could not be readily identified in the field were collected and stored in plastic bags partially filled with sea water for transport to the laboratory. In the laboratory, animals were relaxed in 7% $MgCl_2$ for a minimum of one hour. Specimen were subsequently fixed in 4% formol for 4 hours and later preserved in

95% alcohol. The length and width of contracted individuals as well as the presence or absence of anal teeth were recorded prior to preservation. The preserved specimen were subsequently dissected and the internal structures were described. Detailed drawings of the calcareous ring were made using a stereo microscope fitted with a camera lucida.

Additionally, spicules in the body wall (dorsal and ventral), tentacles, podia and papillae were extracted after digestion of small parts of these structures in javel (1/1) for at least 2 hours. Digested parts were rinsed in distilled water. Spicules were mounted on a glass slide using euparal and observed under a stereo microscope. Samples were also examined under a scanning electron microscope at the Royal Belgium Institute of Natural Sciences, Brussels. In cases where several specimen were collected, one set was preserved for the reference collection at the Resource Center at the Malindi marine park, the rest were used for taxonomic verification in Brussels.

3.3 Results

A total of 31 locations and 130 sites were surveyed from Kiunga in the north to Kisite in the south (Fig. 3.1). At each location between two and ten sites were surveyed depending on the diversity of habitats. Thirty one species were positively identified (Appendix 1), one new species was described *Bohadschia atra* sp. nov (Massin et al 1999) and one species tentatively named *Holothuria arenacava*(Samyn per comm) is still under taxonomic investigation. Two more species *Holothuria sp* and *Bohadschia sp* could not positively be identified to species and are currently under investigation.

As this was the first comprehensive survey of the holothurians of Kenya, it was not possible to make meaningful historical comparisons. The species recorded in this study however are similar to species in the region (Clark and Rowe 1971; Richmond 1997) as well as species recorded by Humphreys's (1981) survey at Mida creek, Kenya. Only five species reported in the above studies were not encountered in the present survey (Appendix 1). The dominant species included *Holothuria atra* that occurs in 23 of the 31 locations surveyed followed by *H. leucospilota* (14), these species were also more abundant than most holothurians (Fig. 3.2). *Bohadschia sp, B subrubra* and *Holothuria nobilis* that all occurred in 11 of the surveyed locations (Table 3.1). When similar sites are compared, marine parks did not have a higher diversity of holothurians with Mombasa marine park recording 14 species compared to Vipingo at 13 holothurians. However from the transect surveys MPAs on average had a higher abundance of holothurians than unprotected areas.

The abundance of holothurians at different sites along the Kenyan coast is highly variable ranging from 0.5 to 7.75 sea cucumbers per $250m^2$ (Table 3.2). The density of individual species is also highly variable ranging from 2.3 individuals per $250m^2$ for a population of *H. arenacava* (a newly described species) to 0.02 individuals per $250m^2$ for *Bohadschia vitiensis* (Fig. 3.2). The highest density of holothurians was recorded in a sandy channel at the Mombasa marine reserve (15 ind/$250m^2$, Fig. 3.3). Hard substrate channels and reefs lagoons also had a higher density of individuals (5 – 8ind/$250m^2$). The number of holothurians was lowest on sea grass beds (0.5ind/$250m^2$).

Seventeen species recorded on the Kenyan coast are of commercial value including the high value species *Holothuria fuscogilva* , *H. nobilis* and *H. scabra* and the medium value species *Thelenata ananas* (Table 3.3). Only *H. nobilis* and *H. scabra* were commonly found in the coastal wide survey (Table 3.1). These species were also always encountered in MPAs.

4 REPRODUCTIVE PATTERN OF COMMERCIAL SPECIES

4.1 Introduction

Information on the developmental and reproductive biology of holothurians is limited (Smiley et al 1991), further, the reproductive patterns of tropical sea cucumbers and the factors that control these patterns are not well understood. No studies on the reproductive patterns of sea cucumbers has been carried out on the Kenyan coast least of all of commercial species. The Kenyan coast is influenced by the monsoons (McClanahan 1988) causing characteristic seasonality especially in seawater temperatures and light. These factors have been shown to influence the reproductive patterns of sea urchins (Muthiga 1996) and other benthic invertebrates including barnacles and oysters (Ruwa and Polk 1994) on the Kenyan coast. Whether these factors are important in controlling sea cucumber reproduction on the Kenyan coast is not known. Studies of the reproductive patterns of key commercial species were therefore carried out with a view to collect information useful for future culture trials.

4.2 Materials and methods

Three main species were selected for reproductive studies based on their commercial importance and their availability including *Holothuria fuscogilva, Holothuria scabra* and *Holothuria arenacava*. *H. scabra* and *H. fuscogilva* were collected jointly with fishermen at Vanga and Shimoni, the major landing beaches in the South coast of Kenya. *H. arenacava* was collected from the Mombasa marine reserve. Ten to twenty individuals of each species were collected monthly, placed in a bucket and transported to the Kenya Marine and Fisheries Research Institutes (KMFRI) laboratory or field station in Gazi.

Individual sea cucumbers were dissected, the coelomic fluid was allowed to drain and the total wet weight of each individual was measured. The gut and gonads were separated and wet weighed. Monthly gut and gonad indices were calculated as 'organ wet weight / total wet weight x 100'. The reproductive pattern was illustrated with plots of mean monthly gut and gonad indices. Sea cucumbers were sexed by observation of pieces of gonadal tubules under a binocular microscope. Correlations between sea water temperature and light were made using pooled sea water temperature data from 1992 – 1998. Light data was collated from Kenya's meteorological station at the Mombasa airport.

4.3 Results

4.3.1 *Holothuria scabra*

The reproductive cycle of *H. scabra* was assessed from February to December 1999. The pattern of reproduction elucidated from gonad index measurements and observations of reproductive cells of 170 individuals indicates a gradual build up of gametes to a peak around October- November when gonad indices reach 6 – 8% of the total body weight (Fig. 4.1). The gonad index then drops sharply in December and remains low until February of the following year indicating the end of spawning. The gonad index is also low in July (< 2%), however this is more likely due to a low sample size of 4 small sexually immature animals. Males and females showed the same pattern of reproduction.

A comparison between the mean monthly sea water temperature and mean monthly gonad index showed no significant correlation (r = 0.35) (Fig. 4.2). In general spawning occurred during the warmer months of the year. A comparison between the mean monthly light measurements and mean monthly gonad indices also showed no significant correlation (r = 0.48) (Fig. 4.3). Again spawning tended to occur at the time of year when light levels were high.

The size of the gut of *H. scabra* measured as the gut index showed variation throughout the year. However this variation did not correlate to the variation in the gonad index despite the fact that these organs share a common space in the coelom (Fig. 4.4). In general however months with high gonad indices corresponded to months of low gut index, however a correlation between mean monthly gonad indices with mean monthly gut indices showed no significant relationship (r = 0.08).

4.3.2 Holothuria fuscogilva

The reproductive pattern of *H. fuscogilva* was also assessed from February to December 1999 (Fig. 4.5). A total of 217 individuals were sampled and gonad indices are low (1 – 2 %) in the early part of the year and increase from May to December to a peak of 6.5%. Gonad indices drop dramatically between December and February and remain low until May indicating the end of spawning. There is a sharp drop in July but we ascribe this to a collection anomaly as animals collected in this month are small and immature.

Of the individuals sampled, 105 were males and 94 were females, (a ratio of 1: 1.1 females to males) not significantly different from a ratio of 1:1. The reproductive patterns were similar in males and females. There was no significant relationship (r = 0.38) between gonad index and temperature suggesting that temperature has no influence on reproduction. Gonad indices were high even when temperatures were low (Fig. 4.6). There was also no significant relationship between gonad index and radiation (r = 0.2) suggesting that light also does not have an influence on reproduction of *H. fuscogilva*. As with temperature, gonad indices were high even at low light (Fig. 4.7). There was a poor correspondence between the size of the gut and the size of the gonad as was similar to *H. scabra* (r = 0.13; Fig. 4.8).

4.3.3. Holothuria arenacava

The reproductive pattern of *H. arenacava* was studied for 24 months between 1997 and 1998. A total of 220 males and 262 females were sampled, a male to female ration not significantly different from 1:1. The reproductive pattern shows a well defined annual cycle (Fig. 4.9) with low gonad indices (2%) in May through June. Gonad indices gradually increase in July indicating the commencement of gametogenesis and by September large oocytes and ova are present in the gonadal tubules. Gonad indices peak the following March at 14% and drop dramatically in April through May indicating the end of spawning. Males and female individuals showed a similar response. Although there was some variability in the gonad indices between years, the general pattern remained the same.

The potential influence of seawater temperatures and light on the reproduction of *H. arenacava* was investigated by correlating mean monthly gonad indices and mean monthly seawater temperatures and light. Both environmental factors showed a significant and positive correlation with light having a stronger response (r = 0.96; Fig 4.10) than temperature (r = 0.75; Fig 4.11). High sea water temperatures and high light values corresponded to high gonad indices.

Unlike the other studied sea cucumbers, we were able to collect *H. arenacava* over an entire lunar cycle during the ripe period. A correlation between mean daily gonad indices and lunar day (new moon = day 0) was therefore performed to investigate the possible influence of lunar periodicity. No significant correlation (r =

0.39) was found between mean daily gonad indices and lunar day (Fig. 4.12) suggesting that no lunar periodicity occurs in this species. There was also no relationship between gonad and gut indices ($r = 0.50$) although there was a tendency for the highest gut indices to occur after spawning when gonad indices were at their lowest (Fig. 4.13).

5 SOCIO-ECONOMIC STUDY

5.1 Introduction

To date very little information has been collected on the social and economic aspects of most fisheries in Kenya and the holothurian fishery is no exception. The viability of any future enterprise related to holothurians will be dependent not only on biological information but also on important external factors of a social, cultural, economic and political nature. Therefore, because of the paucity of information, the socio-economic study undertook a broad approach examining the key socio-economic features of the communities in the study area with a view of assessing the potential for a community based sea cucumber culture pilot project.

5.2 Methods

An initial survey was carried out to identify the key areas for the study. The main criteria used were that the area was close to, or adjacent to an MPA and that the communities of the area utilize the MPA for fishing. A reconnaissance survey was then carried out in the study area to plan for the field data collection phase. The survey was also used to introduce the study to community representatives, district officials and village elders.

Preliminary information was collected during this phase including number, location and size of villages, types of resource use, the concerns and priorities of the communities and conservation issues. Procedures and formalities that need to be observed were also identified and a schedule of activities was developed in order to minimize disruption of livelihoods as much as possible. Logistical requirements for the field data collection exercise were also identified and a local enumerator was contracted to assist the investigator during the study. Key informants were identified based on their knowledge of the area and insight of the main resource use issues.

During the field data collection phase, several techniques were used including questionnaires, interviews, observations and informal discussions with the target groups; the exercise was made as participatory as possible.

The questionnaires included the following basic questions among others:

- What resource use-related activities do you conduct?
- Where do these activities occur?

- Where do you live?
- What is your occupation
- In what age bracket are you
- What is the level of your education
- Do you know about sea cucumbers and are you involved in the fishery
- What is your opinion about the marine protected areas

Many of these questions were further explored in more detailed questionnaires and interviews at the village and at the landing beaches.

5.3 Results

The main study area is located in Kwale district situated in the south of the Kenyan coast. The district covers an area of 8,322 Km^2 and includes the Shimba hills national forest reserve and the Kisite/Mpunguti marine park and reserve and the Diani marine reserve. The main marine habitats that occur in the district include; a fringing reef that extends along the coast 300 to 1000m from shore and patch reefs encompassed within the Mpunguti and Kisite marine park and reserve, sea grass beds in the shallow lagoons and bays and extensive mangroves in Gazi bay and Ramisi estuary.

Eight villages were surveyed including Bodo in Msambweni location, Kiwambale in Pongwe Kidumu location, Aleni, Mwenjeni and Mji wa Pwani in Majoreni sub location and Vanga, Jimbo and Jasini in Vanga location. A total of 152 household heads were interviewed using a haphazard sampling technique, this consisted of approximately 10 % of the population of the area as the area was very sparsely populated making it difficult to cover a larger sample size. 34% of respondents were from Bodo, Ganje and Kilimani villages (Table 5.1). These villages were roughly in the same area and approximately two kilometres apart. The villages usually had the same socio-cultural composition and were mainly composed of clans leaving little room for immigrants. Seventy eight percent of respondents have lived in the village for more than 20 years and have been in these villages since they were born (Table. 5.1).

The main occupation of the communities in the study area was fishing (48% of respondents) however there are very few fish traders in the area (2%). Farming was also a common occupation (33% of respondents) although the rearing of livestock was rare. The land available for agriculture is very limited 34% of households live on one acre, 31% on 1 – 4 acres and 6% on 4 – 8 acres. Farming is therefore subsistence for food crops including cassava but some cash crops like rice and coconuts are also cultivated. In most cases the fishermen also farm especially during the Kusi (SEM) season. There were very few teachers in the area and this is collaborated by the fact that more than 40% of respondents had no education at any level (Table 5.1). A high percentage of the respondents (23%) had however attended the Madarasa (Islamic school).

Most of the respondents were between 18 and 65 years which is not surprising has interviews and questionnaires were targeted at household heads (Table 5.1). Out of 152 households interviewed, 22% were women, and 78% were men. The women who responded did so because their husbands were out fishing or were living in the urban areas due to employment opportunities. The percentage of households headed by women is therefore lower than the actual number interviewed. The male to female ratio was close to 1:1 with most households having an almost equal number of males and females (Table 5.2). Many households also took care of relatives a common practice in Kenya. 65% of households were polygamous with up to two wives. This is not surprising as the dominant ethnic group was the Digo (56% of respondents) who are also Islamic. The Shirazi consisted of 30% of the respondents while 14% were smaller groups including the Bajuni, Luo, Giriama, Mpembe, Ziphana, Mkifundi, Mazrui, Mgunya, Msegeju, Mvumba, Mmasi, Mduruma and Mhutu. These small groups reflect a mixer of many coastal groups along the east coast of Africa and may have migrated from as far south as Mozambique.

Most respondents (93%) were aware of the nearby Kisite Mpunguti marine park and reserve. However there were varying reasons given as to why the area was protected including to guard fish and corals (37%), to generate income for the park service (55%) and for creating employment (28%). However 66% of respondents would like to be allowed to fish in the park. Most respondents thought that the difference between a national park and an unprotected area was the fact that parks had more fish (47%) hence the desire to be allowed into parks to fish. Most respondents did not make the connection between prohibition of fishing and the higher population of fish within parks, some explained that fish are naturally higher in park.

The respondents of the area had a high level of understanding about destructive resource use issues including trapping wildlife, charcoal burning, cutting down trees and setting fires for agriculture (Table 5.3) yet these were common activities in the area. These communities are highly dependant on natural resources for food, fuel, building materials, medicines and even for spiritual rituals in the sacred Kayas (Forest) (Table 5.5). Marine resources including finfish, mangroves, crustacea and seaweeds were especially important to these communities (Table 5.6 and 5.7).

Income from fishing is generally low with up to 41% of respondents earning between 2600 – 3500 Kshs per month (US$ 35 – 48 at that current rate) during the good fishing season, however this reduces to as low as Kshs 800 (US$ 11) in the bad fishing season (Table 5.8). Additional means of livelihood include fishing using Uzio (a reed trap constructed from shore in mangrove channels) (28%), farming (38%) and mangrove cutting (15%) (Table 5.9). Very few respondents are involved in the tourism sector and this therefore does not appear to be a preferred income generating activity (Table 5.10). The low level of education in the area excludes these communities from the tourism sector.

The main villages where sea cucumbers are harvested in the study area are Bodo, Kibuyuni, Sifimoni, Majoreni and Vanga. In most cases different reefs are fished by the different villages usually related to distance from the village which ranges from 5 to 10 Km (Table. 5.12). The main mode of transport is by dugout canoe or traditional sail boat (Ngalawa). Sea cucumbers are collected off the sea floor while skin diving or walking in shallow areas. In most cases the fishers looking for sea cucumbers are also fishing for finfish. The sea cucumbers are then transported to the village, gutted and boiled for 1-2 hours. The body wall of the sea cucumbers is then sun dried and stored to be collected later by a licensed trader.

In addition to the information collected in the villages, fishermen were also interviewed at fish landing beaches of Diani, Gazi, Aleni, Majoreni and Vanga in the south coast and in Mtwapa, Vipingo, Takaungu and Malindi in the north coast of Kenya. Sea cucumbers are also landed on these beaches. The prospect of culturing sea cucumbers was well received.

6 THE HOLOTHURIAN FISHERY IN KENYA

6.1 Introduction

Sea cucumbers were heavily traded at the turn of the century but are currently a minor fishery in Kenya. Records in the Kenya National Archives and coast district reports indicate that this fishery may be overexploited but without key fisheries information it is difficult for fisheries managers to design appropriate management interventions. In this section we compile the little information that is available with a view a better understanding of the status of the fishery.

6.2 Methods

The collection of fisheries information consisted of a desk study of data and information from the Fisheries department, District annual reports and the National Archive reports. Additionally, fishers, traders and fisheries officers were interviewed along the Kenyan coast including Malindi, Kilifi, Takaungu, Kikambala, Vipingo, Kanamai, Jumba ruins, Nyali, Shelley, Tiwi, Diani, Msambweni, Gazi, Vanga and Shimoni. Fisheries data of catches of individual species of sea cucumbers was also collected at Gazi and Shimoni for a period of 3 to 4 months.

6.3 Results

Holothurians are considered a fisheries product and are therefore managed by the fisheries department under the Fisheries Act Cap . The KWS has jurisdiction over the holothurians within marine parks where collection is strictly prohibited. The management of holothurian resources within marine reserves where partial fishing is allowed falls within the mandate of both the fisheries department and the KWS. There is no mechanism however that allows the joint management of these resources within marine reserves as ultimately the fisheries department is responsible for licensing national fishing activities and KWS is not involved in this process. However KWS and Fisheries Dept are negotiating an MOU that will allow the development of a mechanism for joint management of marine resources within marine reserves.

Fisheries data is collected by the holothurian traders and submitted to the District fisheries officers as dry weight of holothurians in Kilograms. There is no requirement to report species and sizes or the original area of the catch. Sometimes catches from Tanga are landed on the Kenyan coast and reported as Kenyan catches. The District fisheries officers compile this information and send it to the provincial fisheries headquarter where the annual catches and the value are collated. There is rarely verification of this information at the landing site or at the traders premises. Additionally sometimes the district data and the provincial data don't tally.

Traders and collectors are licensed by the fisheries department every year. Ideally catch information is supposed to be used to make decisions on the number of subsequent licenses. However collectors are licensed at the provincial headquarters and at the district headquarters and records on numbers of license throughout the coast are poorly kept. Collectors licences state the area one is authorised to collect but there is rarely monitoring to ensure that this is followed. There is also a large number of fishermen who collect holothurians as they carry out their daily fishing activities and this number is not known.

Information from the National Archives indicates that there was concern of over-fishing as early as the 1920s. For example, by 1918 the Provincial Commissioner of Lamu wondered whether there was any future in the holothurian fishery as orders were becoming difficult to fill (KNA Coast 1917-1918). In the 1920 there were fisheries concessions in Malindi, Mombasa and Kipini in northern Kenya. Concessions were granted for three to five years at a time. At this time Chinese workmen were hired to collect and process the sea cucumbers. The trade was considered quite lucrative and Concessionaires fiercely protected their turf.

The holothurian trade today continues at a much lower scale with catches reducing from 90 metric tons in 1988 to 10 metric tons in 1999 (Fisheries data; Fig. 6.1). The value has also declined dramatically from Kshs 15 million in 1992 at the peak to less than Kshs 4 million in 1999 (Fig. 6.2). Because the value of the Kenya shilling has depreciated approximately 50% every 10 years the value in today's terms is considerably less.

Before 1990, much of the fishing was by skin diving, however around 1992 SCUBA diving was introduced and this caused a dramatic increase in the catch (Fig. 6.1). However there was a rapid decline in the catch the following year showing the classic trend of boom and burst that the fishery is prone to.

We followed the catch at two landing sites to identify the main composition of the catch. More than 49% of the catch at Gazi is composed of the high value holothurian *H. fuscogilva* followed by *A. miliaris* at 17%. *Bohadschia marmorata* and *Holothuria sp* contribute 7 to 8% of the catch each (Fig. 6.3). *Holothuria fuscogilva* also contributes 63% of the catch at Shimoni, *H. nobilis*, *Thelenota ananas* and *B. argus* contribute between 10 and 13% of the catch each (Fig. 6.4). Interviews with the local fishermen reveal that the composition changes as the sizes and quantities of the desirable holothurians decreases. Usually fishermen try to catch the high to mid value holothurians but will collect large numbers of low level holothurians to compensate.

We made a rough calculation of the fishing effort by recording the number of fishing days, the total catch (number of individual holothurians) and the number of crew per fishing vessel at Gazi and Shimoni. The catch at Gazi ranged between 12 pieces/man/day and 30 pieces/man /day. This was very similar to the fishing effort at Shimoni which ranged between 20 and 24 pieces/man/day (Table 6.1).

Size frequency histograms were also calculated for the catch at Gazi using body length for *H. fuscogilva* and *H. scabra*. *H. fuscogilva* ranged from 21 to 48 cm body length (Fig. 6.5). More than 67% of the catch was in the range of 31- 43 cm body length. The smallest size class was 21 – 23 cm and consisted of 15% of the catch. According to Conand's 1989 estimates of sex at first maturity, *H. fuscogilva* matures at a length of 32 cm. Assuming that Conand's estimates also correspond to *H. fuscogilva* in Kenyan waters, more than 20% of the catch of *H. fuscogilva* at Gazi is therefore not sexually mature. The size of *H. scabra* in the catch at Gazi ranged from 15 cm to 29 cm. The shape of the size curve was normal with most individuals falling in the 21 – 26 cm size class (Fig. 6.6). The smallest individuals were in the 15 – 17 size class. Conand's (1989) estimates the size at first maturity of *H. scabra* as 16 cm. A small percentage (~ 5%) of *H. scabra* in the catch at Gazi are not sexually mature.

7 ARTIFICIAL SPAWNING AND LARVAL REARING

7.1 Introduction

Holothurians are considered difficult to breed especially when compared to their close relatives sea urchins. Holothurians however have successfully been breed in China, Indonesia, India and Japan and the methods of rearing have been well recorded. It is therefore not inconceivable that holothurians can be breed in Kenya. In this study, we undertook to carry out artificial spawning, fertilisation and larval breeding experiments to record protocols that could further be developed into a pilot holothurian program at the village level.

7.2 Materials and methods

7.2.1 Broodstock

Two main experiments were carried out to develop methods for the maintenance of broodstock. In the first trial, two 5m^3 rectangular concrete tanks were prepared for stocking by layering the tanks with 6inches depth of sand. Ten individuals were stocked in each tank. Tanks were maintained under a plywood canopy to reduce sunlight and temperature. Filtered sea water was continuously pumped through the tanks. These tanks were stocked with *H. atra* which was easily available in the channel next to the KMFRI marine lab. Individuals were feed mashed seaweeds and cabbage.

In the second trial, two 5m^3 concrete tanks were cleaned and filtered seawater was allowed to flow through for several days to allow a layer of microalgae to grow on the tank floor. Again 10 *H. atra* were stocked in each tank.

7.2.2 Induction of spawning and fertilisation

Two main methods were used to induce sea cucumbers to spawn, thermal stimulation and striping of gonads of mature individuals. The thermal stimulation trials were carried out in small glass aquaria, temperatures were elevated by the gradual introduction of hot sea water until the sea cucumbers responded. As soon as spawning commenced, individuals were removed from the aquaria and maintained in trays. Gametes were collected from stripped or thermally induced individuals and mixed together in 1000ml Erlenmeyer flasks with filtered sea water. After an hour a sample of eggs was removed and observed under a binocular microscope to ascertain fertilization.

Larvae were reared in sterilised sea water in 5 lt. Erlenmeyer flasks at a density of 1000 eggs per litre. Temperatures were maintained between 25 and 27^{o}C and gentle bubbling maintained constant aeration of the water. The number of larvae was reduced to 150 – 300 per litre after 48 hours. Thirty percent of the water in the flasks was changed daily. Larvae were fed *Dunaliella sabina and Chaetoceros gracilis* reared at KMFRI.

7.3 Results

Broodstock of *H. atra* were difficult to maintain in both the sandy and bare concrete tanks. *H. atra* exhibited weight loss, and poor gonad development after a period of a week. Several trials were carried out, however the mortality rate of brood stock was very high.

Spawning trials were therefore carried out on brood stock collected from the channel adjacent to the KMFRI lab. Thermal stimulation trials culminated in spawning in 50% of the individuals tested. Fertilisation trials of these individuals also culminated in a high success rate. Fertilisation trials of stripped individuals however culminated in very low fertilisation rates (~ 10%).

Larval rearing trials were successful to the auricularia and doliolaria stages. Rearing was not successful after the feeding stages with larvae displaying characteristics of starvation indicating that the microalgal diet was not appropriate for these larvae.

8 DISCUSSION AND RECOMMENDATIONS

8.1 Holothurian diversity abundance and distribution

This is the first coast wide survey of holothurians of the Kenyan coast. Similar information is not available for any country in the region. Thirty one species were recorded, and if we include species previously recorded but not encountered in this survey the diversity increases to 35 species. The diversity of holothurians however is probably higher as the time spent in each location was limited. For example Samyn (per comm) carried out a two week survey in the Kiunga marine reserve in northern Kenya and recorded 23 species.

Of the 31 species reported, at least two are new records *Bohadschia atra* nov and a species tentatively named *Holothuria arenacava* (Samyn personal comm.). The distribution of holothurians on the Kenyan coast is similar to that found in the Indo-West pacific region (Colin and Arneson 1995). Patterns of distribution were associated with habitat type, *A. mauritiana* for example was only found on reef flats and *Pearsonothuria graeffei* was only found on reef edges. Widespread species like *H. atra* on the other hand were found in reef lagoons and sandy channels while *Stichopus hermanni* was limited to areas of the reef with rubble and hard coral colonies.

Holothuria atra was the most dominant holothurian which is also common throughout the Indo-Pacific (Kerr 1994). The holothurian community on the Kenyan coast probably has not changed much over the years however there are few surveys that can be used for comparative purposes. There were seventeen species of commercial value including the high value species *H. fuscogilva, H. nobilis* and *H. scabra* and therefore there is a good opportunity to develop a pilot culture and stock enhancement project especially in the south coast of Kenya.

8.2 Reproductive patterns

The three species of holothurians that were studied had different patterns of reproduction. *Holothuria scabra* had a relatively short pattern with spawning occurring between October and December, *H. fuscogilva* had a longer spawning period between September and December. *Holothuria arenacava* displayed an annual cycle with spawning occurring between November and the following March (Table

8.1). This is the first time a seasonal cycle has been reported for sea cucumbers at the equator. The pattern for *H. scabra* and *H. fuscogilva* are similar to the reproductive patterns reported for these species in New Caledonia (Conand 1989). *H. scabra* however has been reported to spawn year round in the Philippines (Ong Che and Gomez, 1985).

The factors that control the reproductive patterns of holothurians include temperature and light (Smiley, 1991). There was no correlation however between the reproductive pattern of *H. fuscogilva* and *H. scabra* with sea water temperature or light. However both species tended to spawn in the warmer months. *H. arenacava* on the other hand showed a strong relationship with both sea water temperature and light. Light had a stronger correlation with the gonad indices of this species suggesting that light may have an influence on this species. *H. arenacava* burrows in the sand and therefore light could be a strong cue for the onset of spawning. Further experimentation would have to be carried out for more conclusive evidence.

All three species had a very high fecundity with gonad indices increasing to more than 7% of body weight in *H. fuscogilva* and *H. scabra* and up to 14% *in H. arenacava* which had a relatively thinner body wall. Although *H. fuscogilva* and *H. scabra* were found in low abundance, they were still relatively easy to find and could conceivably be good candidates for culture. *H. arenacava* on the other hand was only encountered in the Mombasa Marine reserve. We would not recommend it for culture at the present time, we do recommend a moratorium of collection in this reserve.

8.3 Socio-economic study

The villages that were studied occur in the south coast of Kenya close to fishing areas where sea cucumbers are currently collected. The communities are low income fishers with subsistence farming being undertaken to supplement food resources. The educational level is low although their knowledge of fishing and information about the marine environment was quite high.

The communities had a good understanding of conservation and other natural resource issues but because of their high dependence on natural resources tended to contribute to the overexploitation of these resources. For example most of fishers were aware that MPAs had a higher abundance of fish, however they attributed this to habitat variability rather than prohibition of fishing. Many fisher would like to be allowed into the marine parks to fish. The low level of education excluded many of the community members from the tourism sector.

In the main villages where sea cucumbers are harvested, interviews conducted with the fishermen revealed that the fishery is currently not very lucrative for the fishers. When asked how the situation could be improved most tended to reply that improved gear including boats and SCUBA gear would help. They were also keen on the prospect of culture. The harvesting of holothurians is a recent phenomenon for these communities and we found no taboos or cultural attitudes towards sea cucumbers. However women were not involved in the fishery even at the processing stage.

8.4 Holothurian Fishery in Kenya

The holothurian fishery has a long history in Kenya dating back to the early 1920s when Chinese fishers were employed by Concessionaires to collect and process the holothurians. Today, fishing is carried out either by individual fishers as they go about their normal business of fishing, or by teams of two to four divers who are provided SCUBA gear by licensed traders. Unfortunately many of these divers are not certified and sometimes have inadequate or faulty gear leading to several diving accidents.

The collection of fisheries data for the holothurian fishery is also not adequate which is similar to most countries involved in this fishery (Conand 1993). Catches are reported as dry weight, there is no requirement to record species, sizes, area of fishing or effort (number of fishermen or harvest time). We estimated catches at Gazi by following a team of divers for several months. Catches averaged between 12 and 30 holothurians/man/day. If we assume that fishers go fishing on average 288 days (McClanahan per comm) per year this would translate to a total effort of between 3456 to 8640 holothurians/man/year.

The holothurian fishery is showing signs of over exploitation, catches have steadily declined over the last 10 years from a high of 90 metric tons in 1988 to less than 20 metric tons in 1999, this is a very minor percentage of the marine catch of the Kenyan coast (5000 metric tons). Interviews with fishers also reveal that smaller and smaller holothurians are being collected and it takes longer to find the high value species. Size frequency measurements of catch at Gazi also reveal that a sizeable percentage of the catch consists of sexually immature individuals. This pattern is similar to many holothurian fisheries world-wide (Conand 1993) and Kenya is not an exception. Holothurians are sedentary and easy to collect and therefore can easily be overexploited. Interviews with the Fisheries department reveal that the department is aware of this trend and is currently reviewing the fishery. Information from this study has been used to stop the licensing of any additional collectors until a thorough review and comprehensive monitoring system has been put in place.

8.5 Spawning and fertilisation trials.

We were able to induce artificial spawning in *H. atra* through thermal stimulation. We were also able to successfully fertilise *H. atra* eggs and rear larvae to the auricularia stage. We were not very successful in maintaining brood stock in the laboratory or rearing larvae to the feeding stages. We were eventually forced to terminate these trial for logistical reasons including power problems and a flow through sea water system that broke down and required a substantial amount of funds to rehabilitate which could not be met by the present project.

8.6 Recommendations

Holothurian fisheries are usually characterized by periods when they are over exploited and then a period in which they recover. These cycles are usually driven by the world market, however over the last few years the pressure on the worldwide holothurian fishery has been particularly intense with the opening up of the Chinese market. In order to have a more sustainable supply of holothurians appropriate management approaches need to be developed. The basis for developing these approaches should include information on the biological resource and key features of the fisheries. We have made some attempt to collect this data.

For example the collection of size frequency data has shown that a high percentage of the catch of holothurians in Kenya is sexually immature. The reproductive patterns of the high value *species H. fuscogilva* and *H. scabra* should also allow limitations of when to collect these species. Other management approaches could include closed areas, closed seasons, quotas and gear restrictions. The banning of SCUBA for example could be an appropriate intervention not only for safety considerations but also to allow depleted stocks to recover.

The current information indicates that the holothurian resources of Kenya are overexploited and in need of urgent intervention. We therefore recommend the following

- That a monitoring system that includes species, sizes and effort should be developed and tested in the south coast and later implemented throughout the coast.
- That there should be a ban on collection of holothurians in marine reserves for a minimum period of three years and that recovery of the holothurian population should be monitored
- That there should be size limitations at least for *H. fuscogilva* (greater than 32 cm body length) and *H. scabra* (greater than 16cm body length) and that information on size frequencies of other high value and mid value species should be compiled and size limits set should this be required.
- That the current moratorium of trader and collector licenses should continue for a period of three years and that recovery of holothurian populations in key areas including Gazi and Shimoni should be monitored
- That a project should be developed to culture holothurians in the laboratory and later tested with fisher communities in south coast.

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Table 3.2. The abundance of holothuria at several sites along the Kenyan coast estimated as the mean number of holothuria in 250m^2 transects. The number of transects is given in brackets.

Location	**Habitat**	**Species**	**Mean density (no./250m^2 transect)**
Barracuda Pt, North reef, Malindi marine park	Leeward reef slope leading to sandy bottom Reef flat	*H. atra* *B. subrubra* *H. scabra* *B. argus* *A. Mauritiana* *H. atra* *B. argus*	*0.6 (10)* *0.5(4)*
Tewa Reef , Malindi marine park	Patch reef , high hard coral cover and sandy bottom	*H. nobilis* *B. argus*	*2 (4)*
Leopard reef, Malindi marine reserve	Rubble reef	*H. atra*	*1.5 (4)*
Northern Pt of North reef, Malindi marine park	Windward reef edge with high cover of soft and hard coral	*H. atra* *H. scabra* *B. Koellikeri* *B. argus*	*1.25 (4)*
Coral gardens, Watamu marine park	Reef edge high hard coral cover	*H. atra* *Bohadschia sp* *B. subrubra*	*0.75 (4)*
Vipingo	Reef lagoon Reef flat	*S. hermanni* *H. hilla* *H. leucospilota* *H. nobilis* *H. atra* *B. subrubra* *B. vitiensis* *A. mauritiana* *S. maculata* *H. atra* *H. hilla* *A. mauritiana*	*5.6 (6)* *1.25 (4)*
Mtwapa channel	Hard substrate with soft coral	*H. nobilis* *H. miliaris* *H. edulis* *T. ananas* *P. graeffei*	*3(4)*
Coral garden, Mombasa marine park	Reef lagoon	*A. lecanora* *A. mauritiana* *B. argus* *B. subrubra* *S. chloronatus* *B. vitiensis* *H. leucospilota* *H. atra* *H. hilla* *Bohadschia sp.*	4.75 (4)
Gazi bay	Seagrass bed	*A. miliaris* *H. scabra* *H. atra* *A. vitiensis*	1.5 (4)
Ras Iwatine	Reef lagoon	*H. atra* *H. leucospilota* *H. hilla*	7.75 (4)

		miliaris *S. maculata*	
Chale Island	Reef edge	*A. miliaris* *H. nobilis* *Holothuria sp.*	1 (4)
Gazi bay	Seagrass bed	*A. miliaris* *H. scabra* *H. atra* *B. vitiensis*	1.5 (4)
Mwazaro	Reef edge	*H. nobilis* *B. argus*	0.5 (4)
Kisite Island, Kisite marine park	Reef edge	*S. chloronatus* *H. atra* *A. subrubra*	14.5 (4)

Table 3.3. Commercial holothuria recorded along the Kenyan coast

Scientific name	Common name	Value	Local name
Actinopyga echinites	Deep-water redfish	Low	
Actinopyga lecanora	Stonefish	Low	Tambi
Actinopyga mauritiana	Surffish	Low	Kijino
Actinopyga miliaris	Blackfish	Low	Kijino mweusi
Holothuria atra	Blackfish	Low	
Holothuria edulis	Pinkfish	Low	
Holothuria fuscogilva	White teatfish	High	Pauni mweupe
Holothuria fuscopunctata	Elephant's trunk fish	Low	Ngoma
Holothuria nobilis	Black teatfish	High	Pauni mweusi
Holothuria scabra	Sandfish	High	Mchanga
Stichopus chloronatus	Greenfish	Low	
Stichopus variegatus	Curryfish	Low	
Thelonata ananas	Prickly redfish	Medium	Spinyo
Thelonata anax	Amberfish	Low	Spinyo mama
Bohadschia argus	Leopard fish	Low	Gobore
Bohadschia marmorata	Chalkfish	Low	Kijino tambi
Bohadschia vitiensis	Brown sandfish	Low	

Table 5.1. Basic socio-economic data

Question	Number of respondents	% of total respondents
Name of village		
- Aleni	25	16
- Mwenjeni	10	7
- Mji wa Pwani	10	7
- Bodo, Ganje, Kilimani	51	34
- Kiwambale	12	8
- Jasini	6	4
- Jimbo	7	5
- Vanga	28	18
- Other	3	1
Number of years lived in Village		
- 1 – 5	12	8
- 6 – 10	6	4
- 11 – 20	10	7
- more than 20	115	78
- no response	5	3
Occupation		
- Fisherman	61	48
- Farmer	42	33
- Farmer/livestock keeper	0	0
- Gleaner	2	2
- Trader	2	2
- Teacher	2	2
- Fishmonger	3	2
- Other	14	11
Age group		
- 18 – 35	54	36
- 36 – 45	38	25
- 46 – 55	28	18
- 56 – 65	15	10
- over 65	7	5
- no response	8	6
Education level		
- None	60	40
- some primary	29	19
- finished primary	12	8
- some secondary	6	4
- finished secondary	5	3
- Madarasa (Islamic school)	35	23
- no response	5	3

Table 5.2. Household composition

Number of persons in household	% Sons	% Daughters	% Other males	% Other females
0	32	34	42	39
1 – 5	61	61	54	59
6 – 10	4	3	1	1
11 – 15	0	0	0	1

Table 5.3. Attitudes towards natural resource use. Respondents were asked to indicate things they did not like about the ways natural resources were being used or impacted upon.

Resource use issue	% Women	% Men
Illegal fishing methods	3	39
Poaching	0	3
Bird hunting	0	1
Trapping wildlife	23	9
Charcoal burning	39	42
Cutting down trees	26	37
Setting fires for agriculture	26	27
Cutting trees for building	3	2
Soil erosion	0	0
Water pollution	39	22
None	6	2
No response	6	9

Table 5.4. Attitudes towards marine reserves. Respondents were asked to indicate good things and bad things about MPAs

Good things	% Women	% Men
Build classrooms	7	21
Provide help to fishermen	19	23
Increase fish catch	6	15
Provide security	23	7
Attract tourists	29	19
Provides employment	19	25
Share revenue	0	2
None	3	12
No response	29	24
Bad things		
Rangers disturbance	45	46
Not allowed to fish	29	41
Far from park therefore do not know	0	2
Don't share resources	0	3
None	0	7
No response	32	21

Table 5.5. Access and importance of natural resources

Resource/Location	% Women	% Men
Firewood from shamba	6	10
Firewood from commons	55	25
Firewood from forest	39	47
Firewood from park	0	0
Water from shamba	6	16
Water from commons	81	62
Water from forest	6	2
Water from park	0	0
Medicines from shamba	0	1
Medicines from commons	23	13
Medicines from forest	6	7
Medicines from park	0	0
Fruits and food from shamba	13	22
Fruits and food from commons	5	6
Fruits and food from forest	0	3
Fruits and food from park	0	0
Fish from commons	0	3
Fish from reserve	26	40
Fish from forest	3	11
Seaweeds from commons	0	1
Seaweeds from marine reserve	0	0
Seaweeds from park	0	0
Sea cucumbers from commons	0	10
Sea cucumbers from marine reserve	0	8
Sea cucumbers from park	0	0
Mangroves from commons	10	8
Mangroves from forest reserve	10	27
Mangroves from park	0	0

Table 5.6. Uses of mangrove resources

Resource use	% Women	% Men
Fuel wood	100	92
Building poles	100	98
Furniture	0	9
Charcoal	0	6
Leaves	0	1
Flowers	0	1
Seeds	6	0
Boat building	0	9
Other	0	0

Table 5.7. Species of Wildlife used for food

Species	% Women	% Men
Gazelles	19	34
Guinea fowls	13	22
Crustacea	13	24
Seaweeds	0	2
Fish	94	93
No response	3	0

Table 5.8. Monthly income from fishing

Monthly income from fishing in good season		
Income (Kshs)	**Number**	**%**
2600 – 3500	25	41
3600 – 4500	6	10
4600 – 5500	5	8
5600 – 6500	10	16
6600 – 7500	2	3
7600 – 8500	1	2
8600 – 9500	1	2
9600 – 10500	9	15
10600 – 11500	1	2
11600 - 12,500	8	13
No response	1	2
Monthly income from fishing in bad season		
800	37	61
1200	6	10
1400	5	8
1600	2	3
1800	2	3
2000	0	0
2200	3	5
2400	3	5
2600	1	2
More than 2800	6	10
No response	2	3

Table 5.9. Income generating activities carried out during non fishing seasons

Activity	% Men	% Fishermen
Inshore fishing using uzio	28	56
Sale of handicrafts to tourists	3	7
Farming	38	76
Mangrove cutting	15	30
Small business	8	16
Use personal savings	7	13
None	3	7
No response	12	23

Table 5.10. Preferred economic activities other than fishing

Activity	% Men	% Fishermen
Mangrove cutting for sale	10	18
Repairing boats	5	10
Ferrying tourist to the park	2	3
Farming	45	89
Small business	28	56
None	2	3
No response	22	43

Table 5.11. Suggestions for solving fishing problems

Suggestions	% Women	% Men	% Fishermen
Acquire modern fishing gears	19	59	100
Acquire skills in modern techniques including aquaculture	3	30	59
Cold storage facilities	3	14	28
Reliable transport to market	23	6	11
Reliable market and Cooperative	23	6	11
No response	35	15	30

Table 5.12. Reefs commonly fished for holothurioids

Village	Reef
Bodo	Kidomoni Langoni Mlimani
Kibuyuni	Sii Island Tanga
Sifimoni	Sii Island
Majoreni	Msojo Island Kikomoni Island Makiandami Tunga
Vanga	Mpwa Midjira

Table 6.1. The catch of holothuria reported at Gazi and Shimoni landing sites between February and June 1998

Location	Month	Fishing days	Total catch (No of pieces)	Total man days	Catch/ man/ day
Gazi	March	9	550	18	30.6
	Apr	16	781	32	24.4
	May	13	405	33	12.3
	June	9	314	26	12.1
Mean		**11.75**	**512.5**	**27.3**	**19.9**
Shimoni	Feb	15	729	30	24.3
	Mar	25	1125	50	22.5
	Apr	12	478	24	19.9
Mean		**17.3**	**777.3**	**34.7**	**22.2**

Table 8.1 Reproductive patterns of four species of holothuria on the Kenyan coast

Species	Reproductive type	Location	Spawning period	Author
	Gonochoric	S. Taiwan	Jun – Sep	Chao et al 1995
Holothuria atra		Red Sea	Year round	Pearse 1968
	Fission	New Caledonia	Nov - Mar	Conand 1996
Holothuria fuscogilva	Gonochoric	New Caledonia	Nov – Jan	Conand 1989
		Kenya	Sep – Dec	This study
Holothuria scabra	Gonochoric	Phillippines	Year round	Ong Che & Gomez 1985
		New Caledonia	Aug – Sep Dec – Feb	Conand 1989
		Kenya	Oct – Jan	This study
Holothuria arenacava	Gonochoric	Kenya	Nov – Mar	This study

Appendix 1.

Check list of the shallow water holothuroids encountered on the Kenyan coast. Species that have been previously reported but not encountered in this study are tagged with a *. *Holothuria arenexcaveo* is a new species currently under review.

ORDER ASPIDOCHIROTIDA

Family Holothuriidae

Actinopyga echinites (Jaeger)
Actinopyga lecanora
Actinopyga mauritiana (Quoy & Gaimard)
Actinopyga miliaris (Quoy & Gaimard)
Bohadschia argus
Bohadschia atra sp. nov
Bohadschia koellikeri (Semper)
Bohadschia marmorata Jaeger
Bohadschia subrubra (Quoy & Gaimard)
Bohadschia vitiensis (Semper)
Holothuria arenexcaveo
Holothuria atra (Jaeger)
Holothuria cinerascens (Brandt) *
Holothuria edulis Lesson
Holothuria fuscocinerea Jaeger *
Holothuria fuscogilva
Holothuria fuscopunctata
Holothuria hilla Lesson
Holothuria impatiens (Forskal)
Holothuria leucospilota (Brandt)
Holothuria nobilis (Selenka)
Holothuria pardalis Selenka *
Holothuria parva Krauss
Holothuria pervicax Selenka
Holothuria scabra Jaeger
Holothuria sp.
Labidodemas semperianum Selenka *
Pearsonothuria graeffei (Semper)

Family Stichopodidae

Stichopus chloronatus Brandt
Stichopus hermanni Semper
Thelenota ananas (Jaeger)
Thelonata anax Clark

ORDER APODIDA

Family Synaptidae

Opheodesoma sp *
Synapta maculata (Chamisso & Eysenhardt)

ORDER DENDROCHIROTIDA

Family Phyllophoridae

Afrococumis africana (Semper)

Figure legends

Figure 2.1. Oceanographic characteristics of the east African coast (Adapted from McClanahan and Young 1996)

Figure 3.1. A map of the Kenyan coast showing the locations of the surveys

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Figure 4.1. The annual reproductive pattern of *Holothuria scabra* in Kenya

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Figure 4.3. The relationship between the mean monthly gonad index of *Holothuria scabra* and the mean monthly radiation.

Figure 4.4. The relationship between the mean monthly gonad index of *Holothuria scabra* and the mean monthly gut index.

Figure 4.5. The annual reproductive pattern of *Holothuria fuscogilva* in Kenya

Figure 4.6. The relationship between the mean monthly gonad index of *Holothuria fuscogilva* and the mean monthly sea water temperatures.

Figure 4.7. The relationship between the mean monthly gonad index of *Holothuria fuscogilva* and the mean monthly radiation.

Figure 4.8. The relationship between the mean monthly gonad index of *Holothuria fuscogilva* and the mean monthly gut index.

Figure 4.9. The annual reproductive pattern of *Holothuria arenexcaveo* in Kenya.

Figure 4.10. The relationship between the mean monthly gonad index of *Holothuria arenexcaveo* and the mean monthly radiation.

Figure 4.11. The relationship between the mean monthly gonad index of *Holothuria arenexcaveo* and the mean monthly sea water temperatures.

Figure 4.12. The relationship between the mean daily gonad index of *Holothuria arenexcaveo* and the lunar day.

Figure 4.13. The relationship between the mean monthly gonad index of *Holothuria arenexcaveo* and the mean monthly gut index.

Figure 6.1. The holothurian catch in metric tons for the years 1984 to 1999 (Source: Fisheries statistics).

Figure 6.2. The value in Kshs of the holothurian catch for 1984 to 1999 (Source: Fisheries statistics).

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Figure 6.5. The size frequencies calculated from body length for *Holothuria fuscogilva* at Gazi, Kenya.

Figure 6.6. The size frequencies calculated from body length for *Holothuria scabra* at Gazi, Kenya.