CURRENT STATUS OF TRAWL FISHERY OF MALINDI-UNGWANA BAY

FINAL REPORT

PREPARED BY:

Kenya Marine and Fisheries Research Institute

P.O. Box 81651

MOMBASA

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CHAPTER I: PHYSICAL ENVIRONMENT AND PROCESSES

FRESHWATER AND SEDIMENT DISCHARGE IN UNGWANA BAY: THE ROLE OF THE TANA AND SABAKI RIVERS

Johnson U. Kitheka

INTRODUCTION

The dynamics of sediment and freshwater discharge into Ungwana Bay by the Tana and Sabaki River systems is still poorly understood. Most of the previous hydrological investigations have focused on their upper catchments (Dunne and Ongwenyi, 1976; Ongwenyi, 1983; Ongwenyi, 1985). The present study shows that the interaction of the two river systems with the Indian Ocean is controlled not only by the intensity of river discharge, but also by the patterns of monsoon winds and astronomical tides. This study established that the exchange of terrigenous sediments as well as that of water between Tana and Sabaki estuaries and the Indian Ocean portray both tidal and seasonal variations. The movement of the plumes within Ungwana Bay was observed to shift in response to changes in the direction and intensity of the monsoon systems, which not only control climate in the region, but also influence the movement of wind-driven coastal ocean currents (Johnson *et al*., 1982; Brakel, 1984). In this study the dynamics of sediment and freshwater supply into Ungwana Bay will be highlighted.

DESCRIPTION OF UNGWANA BAY

Ungwana Bay extents from Ras Ngomeni in the south to Ras Shaka (north of Kipini) in the north Kenya banks (Figure 1). Sabaki River discharges into the bay at its southernmost limit. The bay is shallow with a wide continental shelf whose extent range between 15 and 60 km. The mean depths at high tide during spring tide are 12 m at 1.5 nm and 18.0 m at 6.0 nm. The depth increases rapidly to 100 m after 7 nm. Sediments within the continental shelf are mainly composed of sand and clay mud. Because of strong influence of Tana and Sabaki Rivers, there is no coral reef in Ungwana Bay, but there are rocky platforms to the southern and northern ends. Throughout the coastline, there is a large stretch of sandy beaches and sand dunes made up of terrigenous sediments derived from Sabaki and Tana Rivers.

DESCRIPTION OF TANA AND ATHI BASINS

Tana and Athi Rivers are the most important rivers draining into Ungwana Bay. The Tana River drainage basin contributes 32% of the total river runoff in Kenya. The total length of the river, from its headwaters in Central Kenya highlands to the Indian Ocean is about 1,102 km. The main hydroelectric power (HEP) generating dams are found mainly in the Upper Tana Basin. These include Masinga, Kamburu, Gtaru and Kiambere HEP dams. Masinga dam, constituting the uppermost reservoir impounded 45 km of the 1,102 km long Tana River, resulting in a body of water covering 25 km^2. This dam acts as a high dam, controlling water storage and discharge for the turbines of the other dams located downstream.

Table 1: The main drainage areas in Kenya.

Drainage area	Area (km^2)	% of the total area of Kenya
1. Lake Victoria	49,000	8.4
2. Rift Valley	127,000	21.8
3. Athi (Sabaki) River	70,000	12.0
4. Tana River	132,000	22.7
5. Ewaso Ngiro	205,000	35.1

Sabaki River, also known as Galana-Athi River in its upper course also, drains the central Kenya highlands. It has a basin surface area of 69,930 km^2 (Table 1). The basin is a major agricultural, industrial and urban area. Rainfall in the catchment range between 500 and 1500 mm per annum and evaporation range between 1700 and 2000 mm per annum.

OBJECTIVES OF THE STUDY

The general objective of the study was to establish the contribution of the Tana and Athi (Sabaki) Rivers to the productivity of Ungwana Bays but with a special emphasis on freshwater and sediment discharge.

RESEARCH METHODS

Study of river discharge

River discharges were monitored on monthly basis at the established river gauging stations (RGS) at Malindi (RGS 3HA6) in the case of the Sabaki River and Garsen (RGS 4G2) in the case of the Tana River. Additional river discharge measurements were also made at Kipini in the lower course of the Tana River.

Measurement of suspended sediment concentration and sediment load

Depth integrated samples for the determination of suspended sediment concentrations were drawn from various sections of the Tana and Sabaki Rivers using Niskin samplers. The total suspended sediment concentrations (TSSC) were determined through filtration using Whatman G/F filter papers. The organic sediment component was determined through combustion technique, in which filtered samples were combusted at a temperature of 500^{o}C for 4 hrs. Sediment loads were calculated using information generated on river discharge and suspended sediment concentrations (TSSC and POSC). The monthly sediment loads were integrated in order to determine the total annual sediment loads.

STUDY OF THE ESTUARINE PROCESSES

Sampling stations

Eight sampling stations were established in both Tana and Sabaki estuaries. Station 1 and 2 were located in areas with strong oceanic influences. Stations 7 and 8 were located in estuarine backwater zones in areas with greater river influence. Salinity and water temperature at various depths was measured within the estuaries using Aanderaa Salinometer and an Aanderaa temperature sensor respectively. Measurements were made during low and high tides and during spring tides. The total suspended sediment concentrations (TSSC) and current speed and direction were measured at 5-minutes interval using a turbidity sensor mounted on an Aanderaa Recording Current Meter (RCM-9) with a temperature sensor. The variations of water level due to tide were monitored using Divers pressure gauges, which recorded elevations at an interval of 5 minutes. The mooring depth inside and outside the estuaries ranged from 2 to 5 m. The duration of mooring ranged from 1 to 5 days.

Climatological conditions and monitoring the movement of plumes

The seasonal monitoring of the movement of the Tana and Sabaki plumes in Ungwana Bay was achieved by making periodic observations on the location and extent of the plumes along the Ungwana Bay coast. The speed of longshore current was measured using partially submerged drogues. Information on winds was obtained from secondary sources (Gohil and Pandey, 1995, Ojany and Ogendo, 1986), as well as information obtained from the wind forecasts provided by the Kenya Meteorological Department

RESULTS

DYNAMICS OF TANA AND SABAKI RIVERS

Monsoon seasons and climatic conditions

Tana and Athi-Sabaki River basins in general experience two rainfall seasons controlled by the Southern and Northern monsoons (Ojany and Ogendo, 1986). The Southern monsoon is associated with the long rains, which occur between March and June. However, in the Kenya highlands the peak rainfall occurs in April. The Northern monsoon is associated with the short rains that occur in the period between November and December with the peak rainfall occurring in November. However, there are often large inter-annual variations in rainfall, partly due to *El-Nino* and *La-Nina* southern oscillation phenomena. While in Central Kenya highlands the annual rainfall is of the order 1500 mm, that along the North coast where the estuaries are situated is of the order 900 mm per annum.

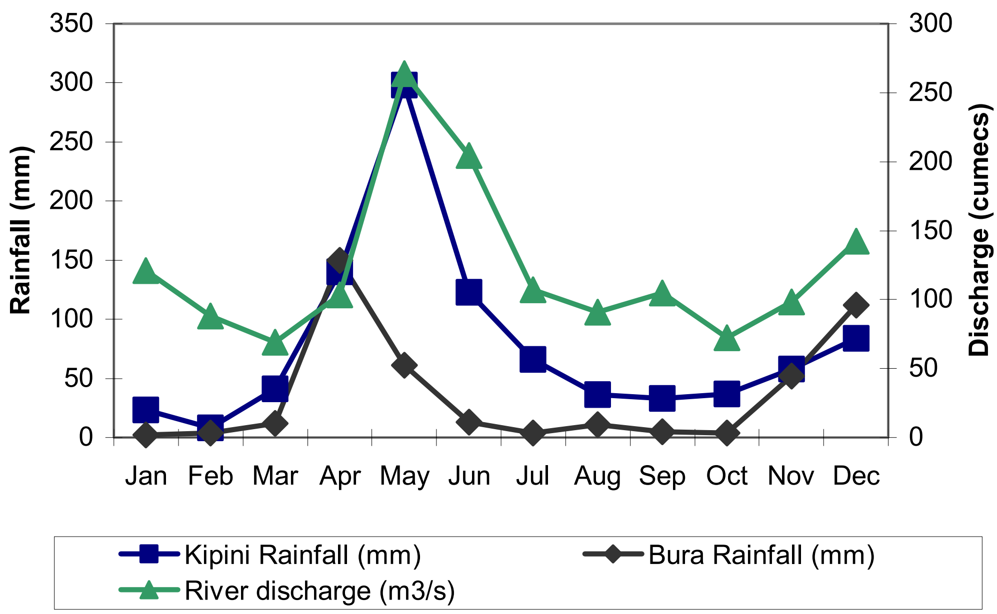

Figure 2: Rainfall and river discharge in the Tana basin.

Seasonal variations of Tana and Sabaki River discharge

Discharge measurements for the Tana River were made at Garsen (RGS 4G2). In the period between February and June 2002, the river discharge varied from 61 to 732 m^3/s (Figure 4). The daily river discharge varied from 8.28 x 10^6 to 63.22 x 10^6 m^3 per day with a mean of 35.75 x 10^6 m^3/day. The long-term data showed that the peak river discharge in the Tana River occurs in May and November (Figure 3). The period of maximum flows during the southern monsoon are between April and July. During the northern monsoon, the maximum flows occurs in the period between November and January. There is thus a phase lag of about a month between peak rainfall in central Kenya and peak river discharge in the lower Tana. There are also significant interannual variations in Tana River discharge as shown in Figure 3. Periods of high river flows are interspersed with periods of low flows associated with droughts.

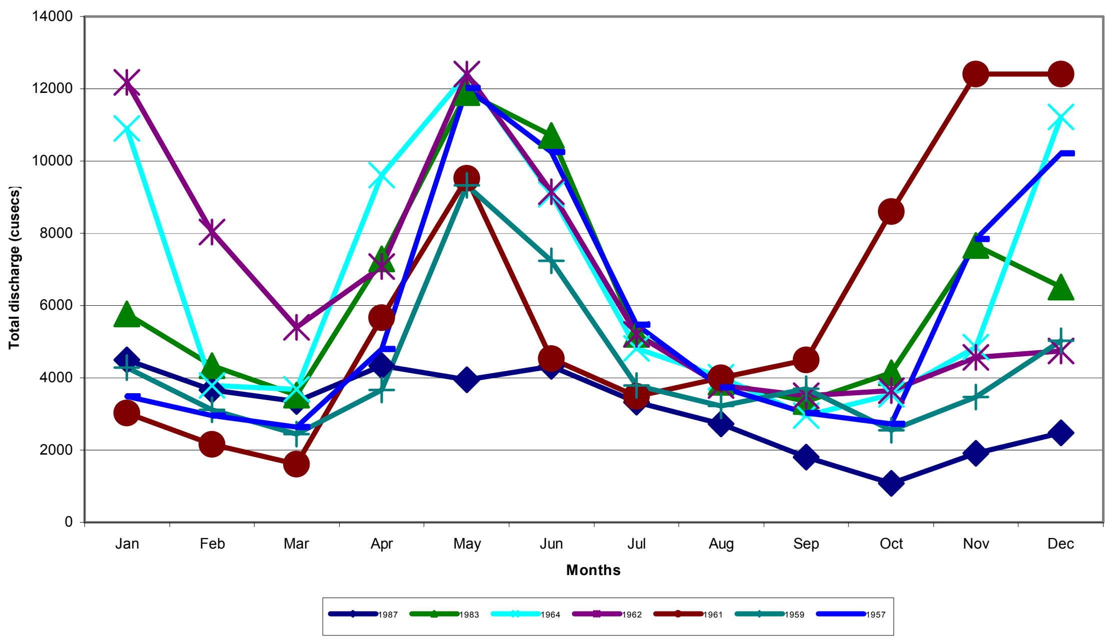

Figure 3: Seasonal and inter-annual variations of Tana River discharge.

Seasonal variations of Sabaki River discharge

Sabaki River basin experiences wide variations in river discharge related partly to the two monsoon seasons. During the southern monsoon, high flows were measured in the period between March and June. The peak river discharge of 382 m^3/s occurred in May 2002 (Figures 4 & 5). During the northern monsoon, high discharges usually occurred in the period between November and January with the peak river discharge in November. The peak rainfall in the upper Athi catchment usually occurs in April. Based on the measurements conducted in the period between March 2001 and June 2002, the river discharge varied from 7 to

382 m^3/s. This shows that Sabaki River discharge varies greatly as compared to that of Tana River. These translates to daily river discharge varying from 0.58 x 10^6 to 33 x 10^6 m^3/day with a mean of 16.79 x 10^6 m^3/day.

Seasonal variations of sediment concentrations and sediment loads in the Sabaki River

As with the river discharge, Sabaki River TSSC showed a relatively large seasonal variations. During the southern monsoon, the peak TSSC of 4.05 g/l occurred in May 2002. The TSSC were generally high in rainy season in the period between April and June 2002 when the TSSC ranged from 0.3 to 4.0 g/l. As compared to TSSC, POSC were relatively much lower as they ranged from 0.0 to 0.3 g/l with the peak in May. The peak sediment discharge of 140,000 tons per day occurred in May 2002. The daily organic sediment load ranged from 5.3 to 8,771 tons/day with the peak in May 2002.

Seasonal variations of TSSC and sediment loads in the Tana River

TSSC in the Tana River showed a relatively narrow seasonal variation as it varied from 0.5 to 1.9 g/l while POSC varied from 0.03 to 0.09 g/l. The peak TSSC of 1.9 g/l occurred in April 2002, about one month before the peak river discharge was experienced in May 2002.

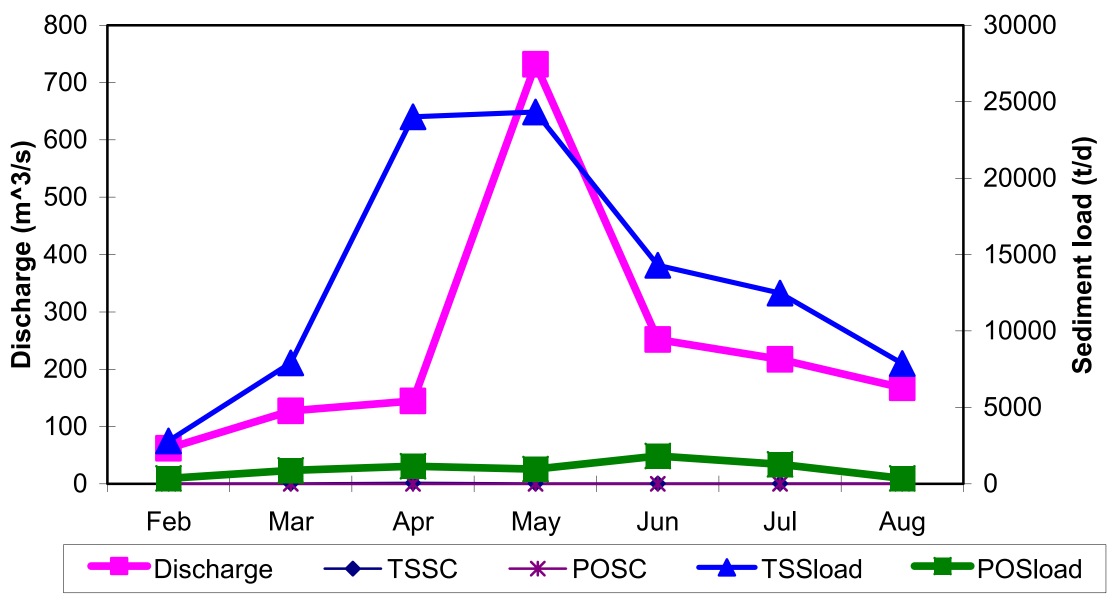

Figure 4: Tana River discharges and sediment fluxes in the year 2002.

The total sediment load in the Tana River was also variable as it ranged from 2,797 to 24,322 tons/day. The peak sediment load occurred in May 2002 (Figure

4). The organic sediment load varied from 356 to 1,144 tons/day. The peak organic sediment load occurred in April 2002. The organic sediment load component varied from 4 to 13 % of the total sediment load. This shows that a large proportion of the sediment consists of the inorganic sediments.

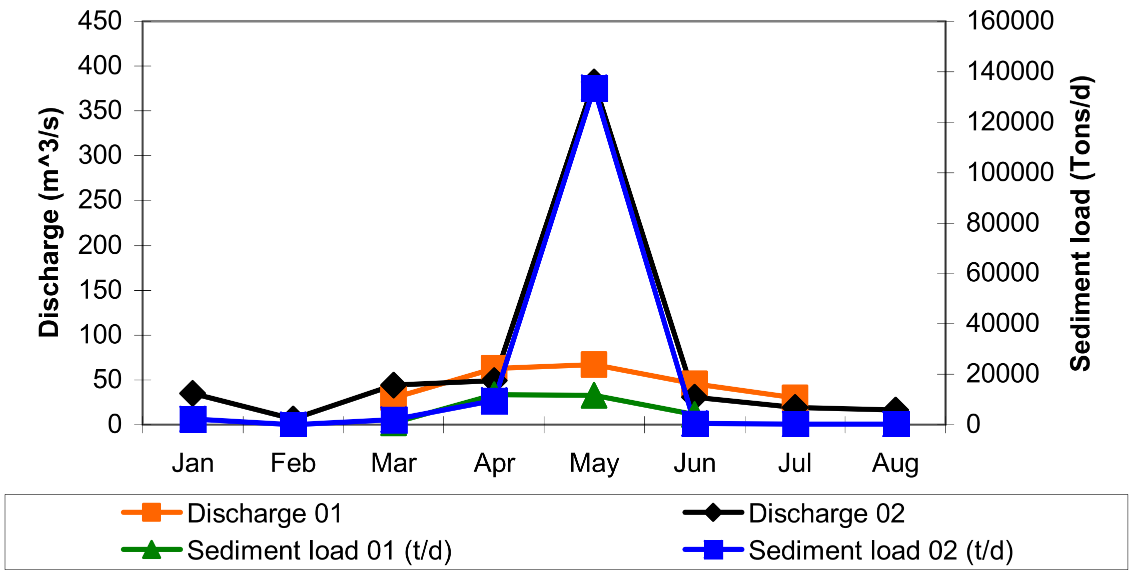

Figure 5: Sabaki River discharges and sediment fluxes in the period 2001-2002.

DYNAMICS IN THE TANA AND SABAKI ESTUARIES

Salinity variations in the Tana estuary

Studies on the spatial distribution of salinity in the Tana estuary showed that there is an exponential decline in salinity from about 32 PSU at the mouth of the estuary to 0.6 PSU inside the estuary. The highest salinity of about 32 PSU occurred in the frontal region located between the mouth and the bridge. During high tide, the ocean water penetrated up to about 12 km into the estuary thus raising the salinity in the estuarine region to values between 25 and 35 PSU. The inner stations were found to have relatively high salinity during high tide when oceanic water enters the estuaries due to tidal forcing.

Salinity variations in the Sabaki estuary

Salinity in the Sabaki estuary was found to drop rapidly in the central zone of the estuary which is a zone of interaction between the river and the ocean. Salinity varied from 0.2 to 12 PSU in the zone fronting the Indian ocean. At low tide, most of the zones inside the estuary experienced riverine conditions with very low salinities of the order 0.2 PSU. This was true for both dry and wet seasons.

Vertical variations of sediment concentrations and salinity in the Tana estuary

Studies on the spatial and vertical distribution of TSSC within the Tana estuary, revealed that there is a region inside the estuary where TSSC tends to be relatively much higher as compared to that in the river and the ocean. This region is referred to as the Turbidity Maximum Zone (TMZ). TMZ was characterized by generally high TSSC greater than 1.0 g/l and it shifted its location with the tides. During low tide, it was found in the frontwater zone adjacent Indian Ocean, and during high tide, it occurred right inside the estuary. In the Sabaki estuary, measurements conducted during spring tide showed that during low tide when there was no tidal effect, the river TSSC ranged from 0.75 to 5.0 g/l. However, during high tide TSSC was usually low as it ranged between 0.15 and 1.0 g/l.

Both Tana and Sabaki estuaries were found to be moderately stratified with vertical TSSC and salinity gradients in the central region. However, in the frontwater zone fronting the ocean, breaking waves enhances rapid mixing of the water column resulting in well-mixed water conditions.

MOVEMENT OF TANA AND SABAKI PLUMES

During the northern monsoon, wind in Ungwana Bay blows from the northern direction. The wind speeds are generally low with a peak speed of 5.5 m/s in January (see also Johnson *et al.*, 1982). The lowest wind speeds occur in May when the wind speed range from 0 to 3 m/s.

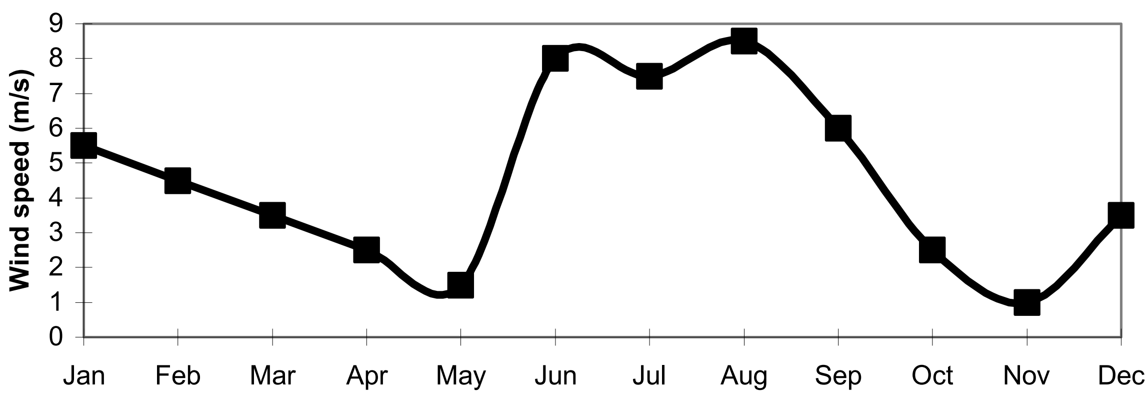

Figure 6: Seasonal variations of the average wind speed during the northern and southern monsoons.

In general, the wind speeds vary from 1 to 6 m/s during the northern monsoon. During the southern monsoon, winds are relatively stronger and blow from the south with either easterly or westerly components (Johnson *et al.*, 1982). The southern monsoon wind speeds are much greater as compared to those experienced during the northern monsoon (Figure 6). The peak wind speeds range from 7 to 10 m/s between May and September. In the period between June and September, wind speeds are usually above 7 m/s with the peak speed of 10 m/s occurring in July and August. Thus, during the southern monsoon, high wind speeds results in rough seas, while the low wind speeds associated with the northern leads to relatively calm sea conditions.

Movement of the Tana plume in Ungwana Bay

During the northern monsoon, winds are usually stronger over Ungwana Bay and Tana plume moves southward at a speed of between 0.20-0.30 m/s. Observations at Kipini revealed that the plume is usually confined along the coast and does not extend more than 5 km to the deep sea. During the intermonsoons, the plume spreads out equally to the North and South of Kipini at a speed varying from 0.20 to 0.60 m/s due to the effects of the river current.

Movement of Sabaki plume in Malindi and southern region of Ungwana Bay

When the wind speeds are low in May, the Sabaki plume spreads into the deep waters about 2-3 km from the shoreline and moves slowly at a mean speed of about 0.40 m/s. During this period, the plume extends northward along the coast at a speed varying between 0.20 and 0.60 m/s upto Mambrui. However, as the wind speed increases in the period between May and June, the plume moves further past Ras Ngomeni up to southern region of Ungwana Bay (see also Brakel, 1984). As the river discharge declines during dry season (during the southern monsoon) the extent of the plume reduces but the zone up to Mambrui remains turbid due to the fact that during low flow conditions, the plume, although small in spatial extent is confined to the North of the Sabaki estuary. During the southern monsoon, the Sabaki plume does not extend far to the south and rarely does it extend beyond Ras Vasco da Gama.

DISCUSSION

This study found that the sediment load varies widely from about 48 to 133,000 ton/day in the Sabaki River compared to the Tana River where the range is narrow as sediment load vary from 2,800 to 24,000 ton/day. Based on the mean daily sediment loads, the annual sediment loads for the Tana and Sabaki Rivers were estimated to be 4.9×10^6 and 24.3×10^6 t/year respectively. There is thus a major difference between the sediment loads of the two rivers. These differences can be attributed partly to the influence of landuse on the hydrology of the two river systems. It seems that within the Tana River system, the seven folk reservoirs trap a large volume of the sediments. Previous studies in the Upper Tana Basin have estimated the sediment load of the Tana before construction of the Seven Folk dams to be of the order 10×10^6 ton/year (Ongwenyi, 1985). Assuming that Ongwenyi (1985) sediment load data is correct, it means that constructions of dams in the Upper Tana Basin lead to a 50% reduction in sediment load. There are no dams in the Sabaki River, but in the last 40 years or so, the problem of poor land use has been compounded by the destruction of forests and other vegetation within the Athi catchment area.

This has led to an increase of Athi (Sabaki) River sediment load from 50,000 t/year in 1950's to the present rate of about 24.0 x 10^6 ton/year. (TARDA Reports)

Table 2: The monsoon seasons and the movement of Tana and Sabaki plumes in Ungwana Bay.

Period	Wind patterns and current system	Climatic conditions	Plume spatial extents
1. Jan-Feb	NM is very strong. Somali current is also strong. Water in the bay flow southward.	Divergence causes dry conditions. River flow is low	A very small plume develops at the mouth of Tana and Sabaki mouths. Tana plume travels 2km. Sabaki plume is absent in the north since it moves to the south.
2. Mar-Apr	NM still prevalent in the north, but in the south there is still SM. Somali current in the north weakens as it meets EACC.	NM-SM convergence hence rainy season begins. River discharges starts rising.	A small or medium plume develops in Tana and Sabaki mouths. Tana plume moves southward towards Sedani and Sabaki plume moves northward up to Mambrui.
3.May-Jun.	SM is firmly established throughout Ungwana Bay. EACC is strong and water moves northward.	SM blows from the sea hence brings heavy rainfall. River discharges are at their maximum.	Tana and Sabaki plumes moves northward. Sabaki plume extents upto Ras Ngomeni and Mambrui. Tana plume moves northward upto Ras Shaka, mid way to Lamu Islands. Plumes are confined along the coast (< 5 km from the coastline).
4. Jun-Sep.	SM is still present south of Ungwana bay. Somali current starts flowing southward. EACC is still present in the southern region.	Divergence of NM winds occurs so dry conditions develop. No rainfall, but to the south, cool conditions ensues.	Tana and Sabaki plume reduces in their size and small plumes present are confined within the mouths of the estuaries due to low flow conditions. Tana plume extents upto Sedani. Sabaki plume does not move beyond Mambrui.
5. Sep-Oct	SM is very weak in the south but NM is strengthening in the north. Somali current starts moving southward.	Some convergence of NM-SM winds brings little rainfall. But conditions are generally dry.	Tana and Sabaki River discharges are very low with very small plumes at their mouths. Sabaki plume is confined along the coast at its mouth. Tana plume starts moving southward due to NM in north Kenya banks.
6.Nov.-Dec	NM is well developed and Somali current is strong and flows southward.	Convergence of NM and SM occurs resulting in heavy rainfall. High river discharge results.	High river discharges of Tana and Sabaki rivers results in large plumes. Tana plume moves southward upto Mto-Tana and Sedani. Sabaki plume moves southward to Malindi Jetty but does not pass Ras Vasco da Gama.

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Source: Wind speed and directions extracted from the Atlas of Surface Wind vectors in the seas around India by Gohil and Pandey (1995). Wind and climatic conditions also obtained from Ojany and Ogendo (1985). NM = Northern monsoon; SM = Southern monsoon.

Table 3: Wind patterns and their main characteristics and influences in Ungwana Bay.

	Month	Wind speed (mean) (m/s)	Season	Typical features of wind
1.	January	5-6 (5.5)	NM	Wind blows from N-E direction with speed varying from 5 to 6 m/s. Somali current flows southward at its peak speed.
2.	February	4-5 (4.5)	NM	Wind blows from N-E direction with speed of 4-5 m/s.
3.	March	3-4 (3.5)	NM	Wind speed in the bay reduced, but is still NE trade wind.
4.	April	2-3 (2.5)	NM/EM	Wind blows from the east at low speeds.
5.	May	0-3 (1.5)	SM	The beginning of SM north of the equator. Wind blows from southerly direction causing heavy rainfall and hence flows from Tana and Sabaki Rivers. Somali current is at its lowest speed and changes direction after meeting EACC in Ungwana Bay.
6.	June	7-9 (8)	SWM	Wind blows from southwest direction from land hence conditions are dry. EACC flowing northward is well developed.
7.	July	5-10 (7.5)	SM	Wind blows from southerly direction with high speed of upto 10 m/s. Cool conditions results. EACC is well developed.
8.	August	7-10 (8.5)	SM	Wind blows from the south. East Africa Coastal Current (EACC) is also well developed
9.	September	5-7 (6)	SM	Wind blows from the south.
10.	October	1-4 (2.5)	SM	Wind blows from the south but with low speed
11.	November	1-2 (1)	NM/EM	Wind shifting southward and blows from northern and easterly direction. Convergence of NM and SM winds occurs causing rainfall and high flow from Tana and Sabaki Rivers.
12.	December	3-4 (3.5)	NM	Wind blows from the north in northern direction.

Source: Wind speed and directions extracted from the Atlas of Surface Wind vectors in the seas around India by Gohil and Pandey (1995).

From current data, the movement of the Sabaki and Tana plumes along the coast in Malindi and Ungwana Bays seems to be driven by the longshore drift, which is generated when wind-driven waves approach and break at the coast at oblique angle. In the past, various workers have attributed the movement of the plume south or north of the bay to the coastal current systems such as the Somali current and the East African Coastal current (Brakel, 1984). It is important to note that the two current systems are usually confined in the deep waters beyond the continental shelf (Johnson *et al*., 1982). Rarely do the plumes from Tana and Sabaki Rivers spread seaward beyond the limits of the continental shelf.

In addition to the winds, tidal forcing is important in shallow waters since it is responsible for moving the plume in and out of the estuaries. It also influences sediment flocculation by driving in high salinity oceanic water into the estuaries where it meets freshwater from the rivers. The differences in the strength of wind during the two monsoon seasons perhaps explain why the Sabaki plume spreads to a relatively greater distance northward as compared to southward (Brakel, 1984). This has been attributed to relatively stronger winds in the southern region of Ungwana Bay during the southern monsoon, which generates stronger northward flowing longshore current. The relatively weaker northern monsoon generates weaker southward flowing longshore current in the southern region of Malindi Bay. This partly explains why the Sabaki plume does not destroy the coral reef complex south of Malindi, which is less than 5 km from the mouth of Sabaki River. However, because Sabaki plume moves a relatively greater distance northward, no coral reef complexes have been established in the southern region of Ungwana Bay. In the northern region of Ungwana Bay, the northern monsoon wind is usually stronger hence Tana plume spreads much further southward. The combined effects of the movement of Tana and Sabaki plumes means that Ungwana Bay is fully subjected to the influences of the Tana and Sabai River systems. This explains lack of coral reef complexes in the bay and presence of terrigenous sediment throughout the bay.

Conclusions

This study has established that the discharges of the Tana and Sabaki Rivers into Ungwana Bay are reasonably variable. In case of both rivers, the peak flows occur in May during the southern monsoon and December during the northern monsoon. The suspended sediment concentrations are also variable for both rivers. In case of the Tana River there is a phase lag between peak Tana River discharge in May and peak sediment concentrations in April. In case of the Sabaki River, there is no well-pronounced phase lag between sediment concentration and river discharge. In both rivers, most of the sediments in transport are inorganic in nature with very small organic component which increases during the dry season.

The study also established that the movement of Tana and Sabaki plumes in Ungwana Bay changes direction in respect to changes in the monsoon wind direction. The plumes are usually confined along the coast and do not extend beyond the continental shelf where the coastal current systems operate.

The heavy discharge of terrigenous sediments and huge volume of nutrient-laden freshwater from Sabaki and Tana Rivers probably explains why the Ungwana Bay is the richest and most productive fishery ground along the Kenyan Coast. This means that the management of the fisheries within Ungwana Bay cannot be successful without the management of landuse and water abstraction within the Tana and Sabaki River basins. This study is still going and more conclusive data is expected to be available at the end of the current monitoring programme for the Tana and Sabaki Rivers.

Acknowledgement

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References

Brakel, W.H (1984). *Seasonal dynamics of suspended sediment plumes from the Tana and Sabaki Rivers, Kenya: analysis of landsat imagery*-Short communication. Remote-sensing of the Environment. Vol. 16, 165-175.

Dunne, T and Ongwenyi, G.S (1976): *A new estimate of sediment rates in the Upper Tana River.* Kenyan Geographer 2(2): 14-29.

Ojany. F.F and Ogendo, R.B (1986): *Kenya: A study in physical and human Geography*. Longman Kenya, Nairobi, 228.

Ongwenyi, G.S (1983): *Development of water resources*. In Ojany. F.F and Olson. S (Editors): The Kenyan Geographer-special issue on the Proceedings of the Nairobi workshop (4-8th August 1981)-Strategies for developing the resources of the semi-arid areas of Kenya.36-47.

Ongwenyi, G.S (1985). *Problems of landuse and water resources management in the Upper Tana catchment in Kenya*. In: Lundqvist, J; Lohm, U and Fakenmark, M (Editors): Strategies for river basin management. Reidel Publishing Company. 123-130.

Gohil and Pandey (1995). *The Atlas of Surface Wind vectors in the seas around India.* ISRI, Ahmedabad.

Johnson, D.R., M.M Nguli and Kimani, E.J (1982). *Response to annually reversing monsoon winds at the southern boundary of the Somali current*. Deep Sea Research. Vol. 29(10A). 1217-1227.

Schneider, H.M (2000): *Sediment sources to Masinga Dam*. In Gichuki, F.N; Mungai, D.N; Gachene, C.K and Thomas, D.B (Editors): Land and water management in Kenya-towards sustainable land use. Proceedings of the fourth national workshop (Kikuyu, February 15-19, 1993). 47-54.

Ruwa, R.K., Muthiga, N., Esposito, M., Zanre, R., Mueni, E and Muchiri, M (2001)-*Prawn Fishery in Kenya.* Report of the Scientific Information and Conservation sub-Committee-Marine Waters. Prawn Trawling Task Force, 8p.

Partners in Science (1991) -*A Kenyan - The Netherlands Co-operative Research Programme in Marine science off the Kenya Coast-1990-1995*. Hague, the Netherlands, 74p.

SOME IMPORTANT HYDRODYNAMIC ASPECTS OF UNGWANA BAY

Kirugara

INTRODUCTION

Water circulation and freshwater input from the Tana and Sabaki rivers are perhaps the most critical processes influencing the ecology of the Ungwana bay prawn fishery. The characteristics of the Somali and East African Coastal Currents that bathe the bay and distribute nutrients, plankton, and the fish larvae is important. The salinity temperatures fields are determined by interaction of the freshwater and the oceanic waters. These physical factors influence the distribution of prawns that spend part of their life cycle in shallow estuarine-blackish waters and other in purely offshore oceanic waters.

OBJECTIVE

To describe the water circulation in Ungwana Bay and relate the distribution of the salinity, temperature and turbidity fields to the hydrodynamics and the distribution and migration of prawns

METHODS

Self-recording oceanographic instruments were deployed at different sites within the bay for data collection. A current meter was deployed along the three chosen transects of 1.5 nm, 4.0 nm and 6.0 nm from the shore to measure current speed and direction. A second self-logging instrument recorded time series data on salinity and temperatures. To compliment this data, a third instrument, a self-recording pressure gauge deployed to measure tidal variation throughout the days of the cruise. All the instruments measured the different parameters on a ten-minute interval basis.

Additional salinity temperature profiles were made using a hand held salinity temperature sonde on selected sampling stations on the transects. Salinity and temperature were used as tracers for different water masses and to give a good indication of where the water masses originate. Bathymetry data was taken using an echosounder and a global positioning system every 15 minutes along all the chosen transects

RESULTS

Bathymetry

The length of the bay from to Kipini to Kalifi is 32.4 km and the width from 1.5 to 6.0nm is 8.1 km. Hence the study area is 262.4 km^2. The Bay slopes gently seawards without any distinct channel systems. This excludes the possibility of currents being forced along any topographic features. The bay is therefore subjected to varying effects of tides, river and wind forcing. The mean depth at low spring water is 10 metres.

Salinity and Temperatures

Surface Salinity

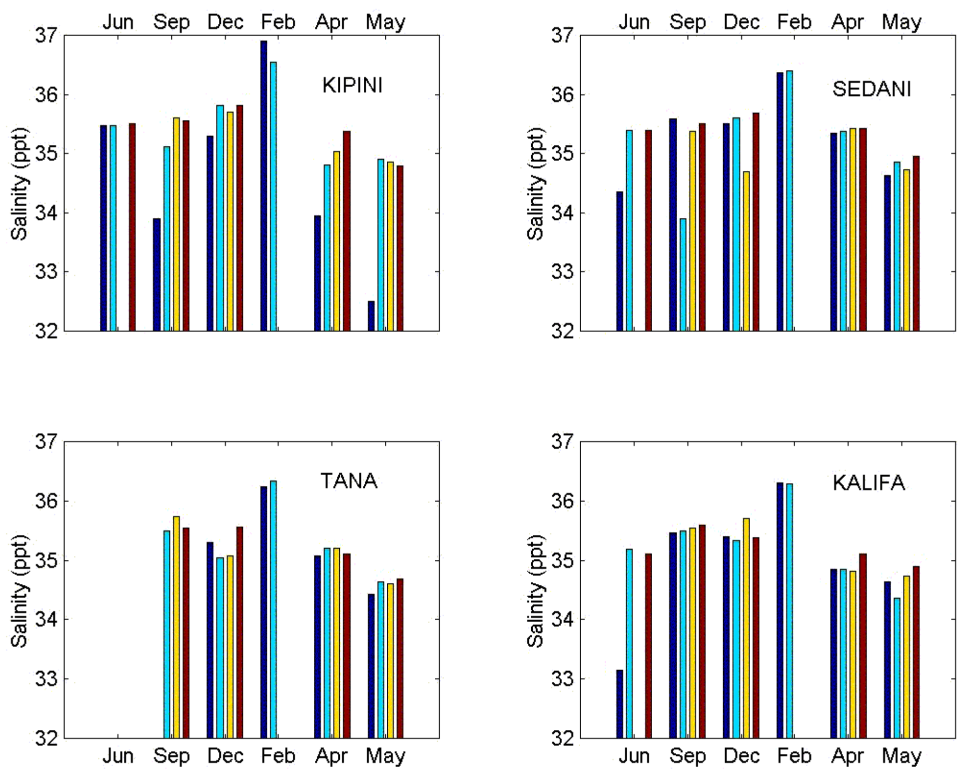


Fig 1. Surface salinity measurements from all stations

The Bay consists of purely oceanic waters with salinity always greater than 34 psu throughout the year (Fig. 1). The observed plume is not salinity dominated. It is evident that the tributary at Kipini is the only significant inlet of freshwater since a significant lowering of the salinity field is recorded during the wet season and localized estuarine circulation may occur between the mouth and the 1.5 nm transect. Statistically there was no significant station effect, and distance from shore effects on surface and bottom salinity and temperature (Fig. 2). The plume that is observed is therefore turbidity based and not salinity or temperature based. A salinity plume is however localized at Kipini during the rainy season and extents to 1;.5 nm from shore

The salinity fields show seasonality effects with the highest salinity observed during the NE monsoon season with evident characteristics of the Somali current waters.

Bottom Salinity

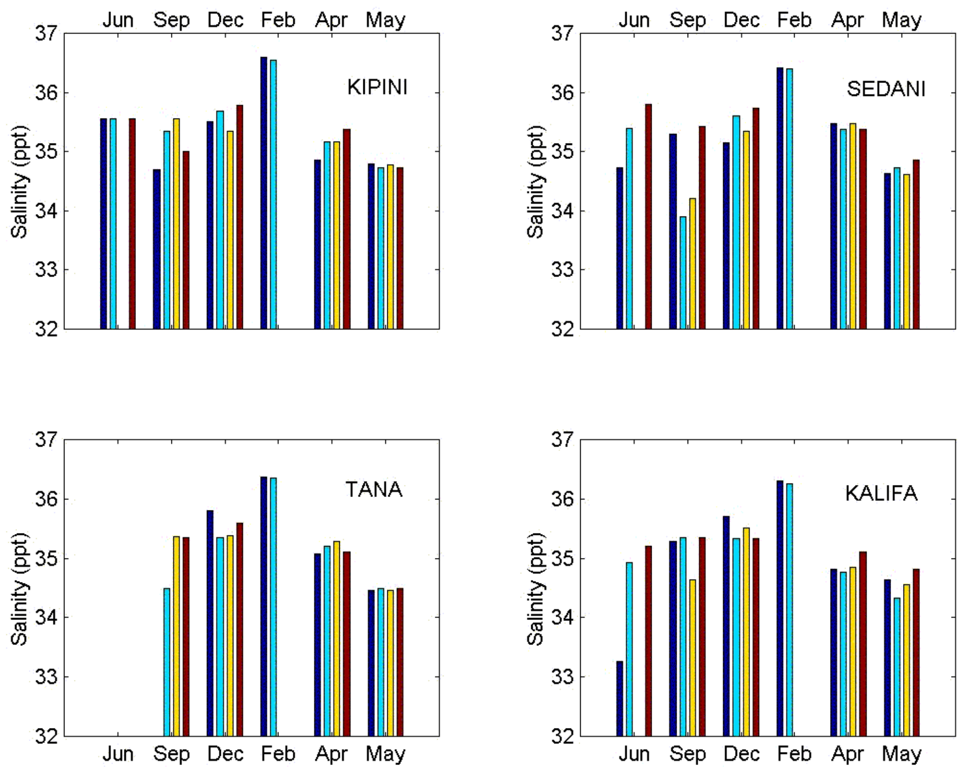


Fig 2. Bottom salinity measurements from all stations

Tides

The tides of Ungwana Bay are semidiurnal and the tides goes upstream into the rivers. The tidal range is similar to Mombasa and in phase with tides observed from Lamu Tide station. The flood currents have a northward and Eastern component while the ebb currents and have a southward and western component. Ebb currents are stronger than flood currents and integrated over one tidal cycle (Fig. 3). There is a net southward flow at 1.5 and 5.0 nm and a northward flow at 1.5 nm.

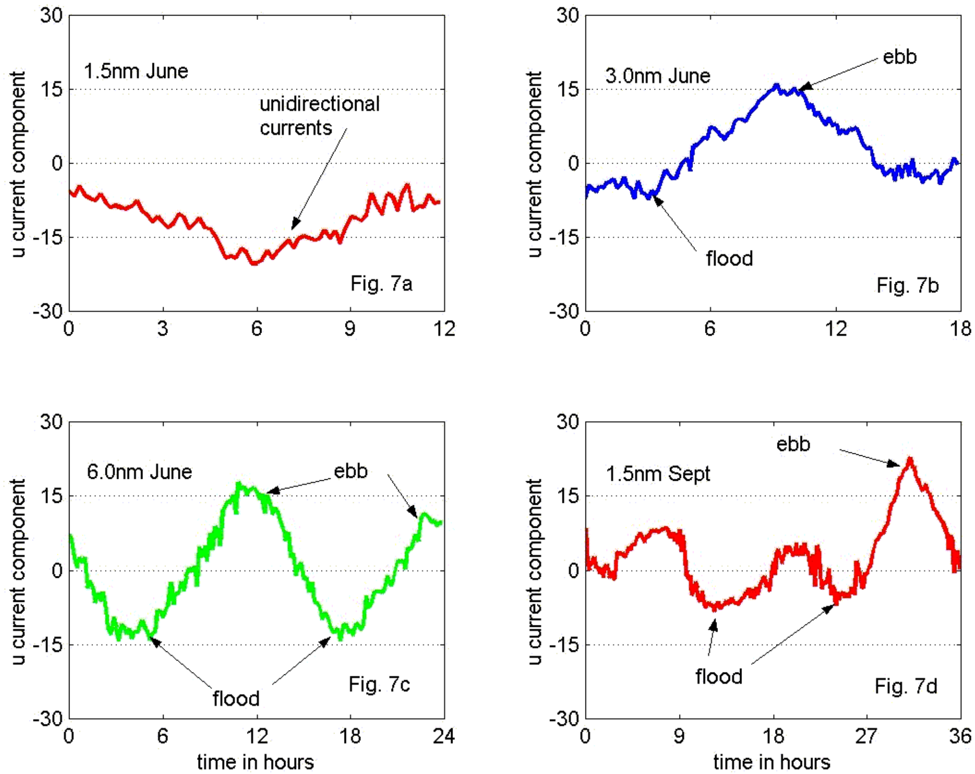


Fig 3. Resolved current velocities at different transects

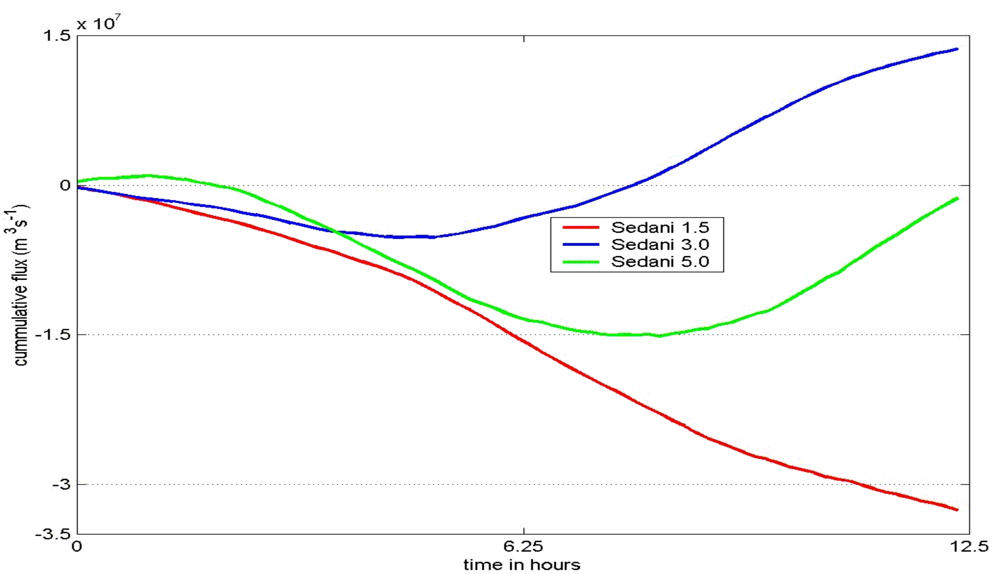


Fig. 4. Fluxes of water at different transects

DISCUSSION

River influence is highly localized at Kipini. The plume in Ungwana is turbidity dominated and this is an important aspect in prawn distribution. A crucial link that was not investigated during this study was the attempt to quantify the fluxes of sediments into and out of the bay (Fig. 4). Generally, the seasonal fluctuations of the river discharges from the Tana delta play a very important role by influencing the nature of the bottom substrate as they deposit terrigenous sediments. Secondly, the turbidity of the water caused either by the waves stirring the bottom also contributes to the turbidity of the waters.

There is a net southward tidal circulation and a net southward transport of sediment almost throughout the year at 5-8 cm/s. Other factors that may be important are the longer-term circulation by low frequency wind effects especially during the SE monsoon. This phenomena has also implications on fluxes of salinity and temperature modulated by the hydrodynamics integrated within the monsoon cycles.

ZOOPLANKTON ABUNDANCE, DISTRIBUTION AND SPECIES COMPOSITION IN UNGWANA BAY.

James Mwaluma

INTRODUCTION

The life cycle of the penaeids occurs partly in estuarine or shallow brackish water in mangrove creeks and in oceanic waters. The aim of collecting zooplankton was to establish the abundance and distribution of the larval stages of prawns, fish and other fishery resources in Ungwana bay. This is an important aspect in predicting parameters that control the breeding seasons, nursery areas and migration patterns of Fisheries resources.

OBJECTIVE

To estimate the secondary productivity of Ungwana Bay with special emphasis on the abundance and distribution of Caridea, Brachyuran larvae, Fish eggs and larvae.

RESEARCH METHOD

Zooplankton were collected aboard the trawler using a 500 μm mesh size plankton net for five minutes at a constant speed of 1.5 knots at each station. Samples were collect at Mambrui, Kalifa, Tana, Sedani, Kipini and Kipini North in June (2001), September,(2001) October (2001), November(2001), (December

(2001), January(2002), April (2002) and May (2002). Sampling was undertaken on transects at 1.5, 2.0, 3.0, 4.0 and 5.0 nautical miles. Collected samples were preserved with 5% formalin for analysis at the KMFRI laboratory.

Results

Peak abundance of Zooplankton and Caridea was found to occur in the rainy periods of November/December and May with abundance of 303 $no.m^{-3}$ and 150 $no.m^{-3}$ respectively (Figure 1 and 2). Caridea were found distributed in the 2.0 nautical mile zone (Figure 2). Fish eggs were abundant in November and December with abundance of 264 $no.m^{-3}$ and 351 $no.m^{-3}$ respectively (Figure 2). They were found mainly distributed stations between 1.5, 3 and 5 nautical miles (Figure 3). Fish larvae were abundant in May (400 $no.m^{-3}$) and found distributed mainly in 1.5 nautical mile zone (Figure 3). Brachyuran larvae were abundant in May (4000 $no.m^{-3}$), and were found distributed mainly in the 1.5 nautical mile zone (Fig. 3).

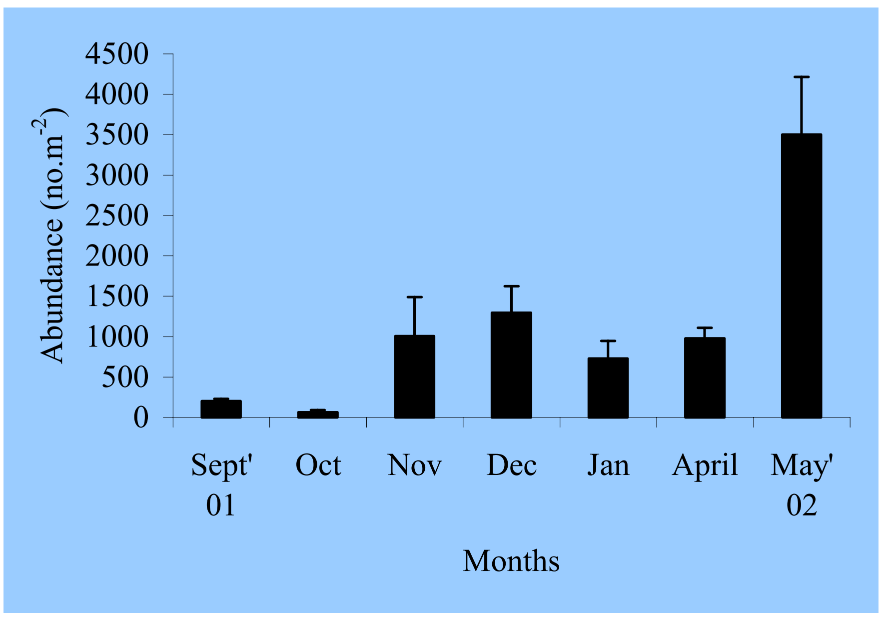


Fig 1. Mean abundance of zooplankton in Ungwana bay.

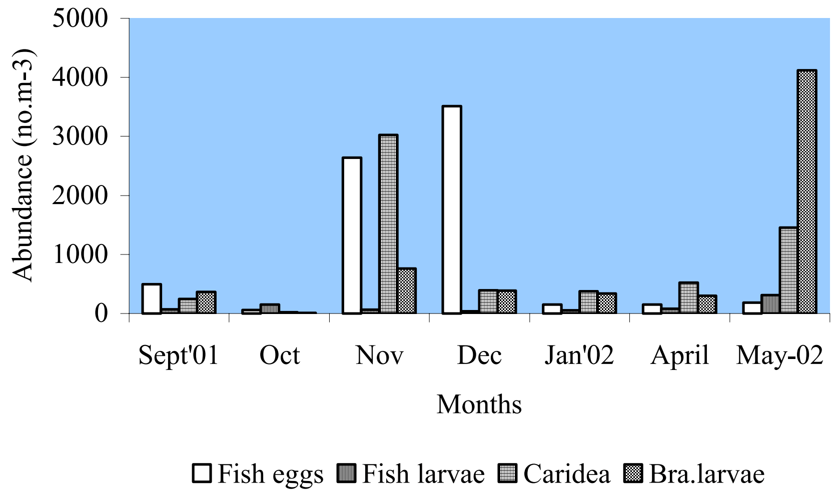


Fig. 2 Seasonal abundance on important zooplankton groups in Ungwana Bay.

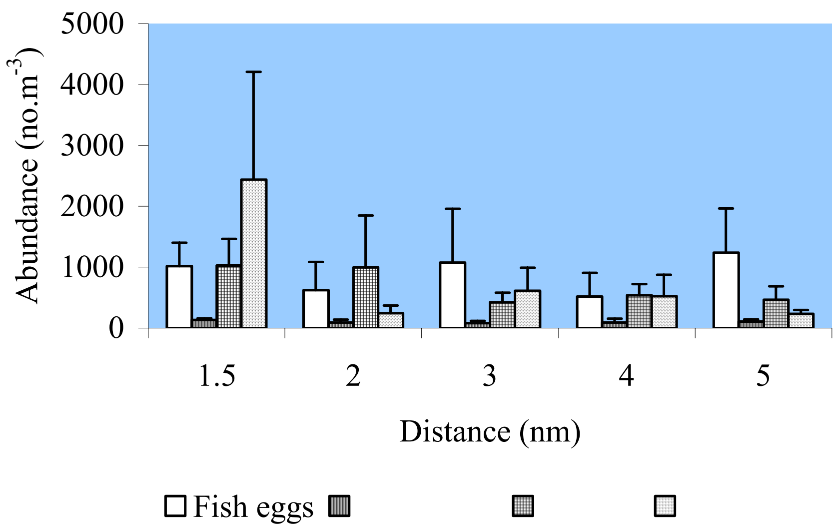


Fig 3. Distribution of important zooplankton groups in Ungwana Bay.

Conclusions

Zooplankton were abundant during the rainy season due to high nutrient input into the bay. The plankton (phyto and zooplankton) are normally consumed as food for the early life history stages of caridea, fish and crabs. Consequently high abundance of these groups was found to occur during the same period. The distribution of these groups in Ungwana bay may be due to a combination of various factors like substrate type, salinity, plankton concentration and currents. Fish eggs were abundant during the NE monsoon (November/ December) which is a period of comparatively high salinity and more stable waters indicating a peak spawning season. Similarly high abundance of Caridea (prawn juveniles) in November and May signals some spawning patterns. However they seem to prefer the muddy substratum which is found around 1.5 - 2.0 nautical miles. Abundance of Caridea beyond the 2.0 nautical miles declines as the area starts to become rocky. Brachyran larvae and Fish larvae seem to thrive during the rainy season (May) in nearshore areas 1.5 nm. Further offshore their abundance declines.

Zooplankton in Ungwana bay are rich and abundant especially during the rainy season. For sustainable utilization of the Ungwana Bay fisheries, management guidelines must recognize nursery areas and the breeding season identified in this study.

SEDIMENT COMPOSITION AND CHARACTERISTICS IN THE MALINDI - UNGWANA BAY

Pamela Abuodha

The richest fishing grounds in the Ungwana bay are within 6 nautical miles from shore, in depths less than 15 m. Prawns are bottom dwellers and are known to prefer a muddy substrate. Rocky bottoms that occur in some parts of Ungwana bay are not suitable to trawling.

OBJECTIVES

The study was designed to map out the benthic environment in the Kipini- Malindi area with the aim of developing an understanding on the control of the benthic environment on prawn distribution and trawling. Bathymetrical and geomorphological studies were undertaken to classify and map the bottom habitats and evaluate environmental factors affecting the bay fishery.

STUDY METHODS

One year sampling was carried out from June 2001 to May 2002. Sampling was done along transects at 1.5, 3.0, 4.0 and 5.0 nautical miles. These stations were located from North to South, Kipini North, Kipini, Sadani, Tana, Kalifi, and Mambrui (Fig 1). Mambrui consisted of Sabaki and Malindi. Sampling was divided into a monitoring survey and a scientific cruise. Cruise months were June, September, December, April and May. Monitoring months were October, November and January.
Collected bottom surface samples were collected on board the trawling vessel. The sand and silt fractions were then sieved through a nest of sieves to separate the sand and silt fraction.

RESULTS

Sedimentation and erosion rates

Bathymetric profiles indicate the offshore extent of the continental shelf off Kipini as 22 Km. At Kipini the depth profiles of 1984 is slightly different from that of 1993 showing that there has been a slight sedimentation in this area at a rate of + 1.4 $myear^{-1}$. At Sadani the continental shelf extends up to 25 km and slight erosion was noted at Sadani at a rate of – 0.2 $myear^{-1}$ and a built- up (sedimentation) at a rate of + 1.0 $myear^{-1}$.

At the Tana estuary the shelf extends up to 27 km offshore and no changes in depth were recorded between 1984 and 1993 along Tana transect. Within the Kalifi transect, the continental shelf extends
up to 30 km. It can also be observed that the depth profiles in 1984 and 1993 remained almost stable. Depth profiles taken during the 2001/2002 sampling have been reported in a separate report.

Sediment composition

The bottom character of the whole of Ungwana bay is mainly composed of siliclatic sediments (Fig. 2d). This is related to terrestrial source through the Sabaki and Tana rivers. Variations in grain size during the different monsoons was noted.

Fig. 2a. Mud content observed in the Kipini – Malindi area during strategic sampling.

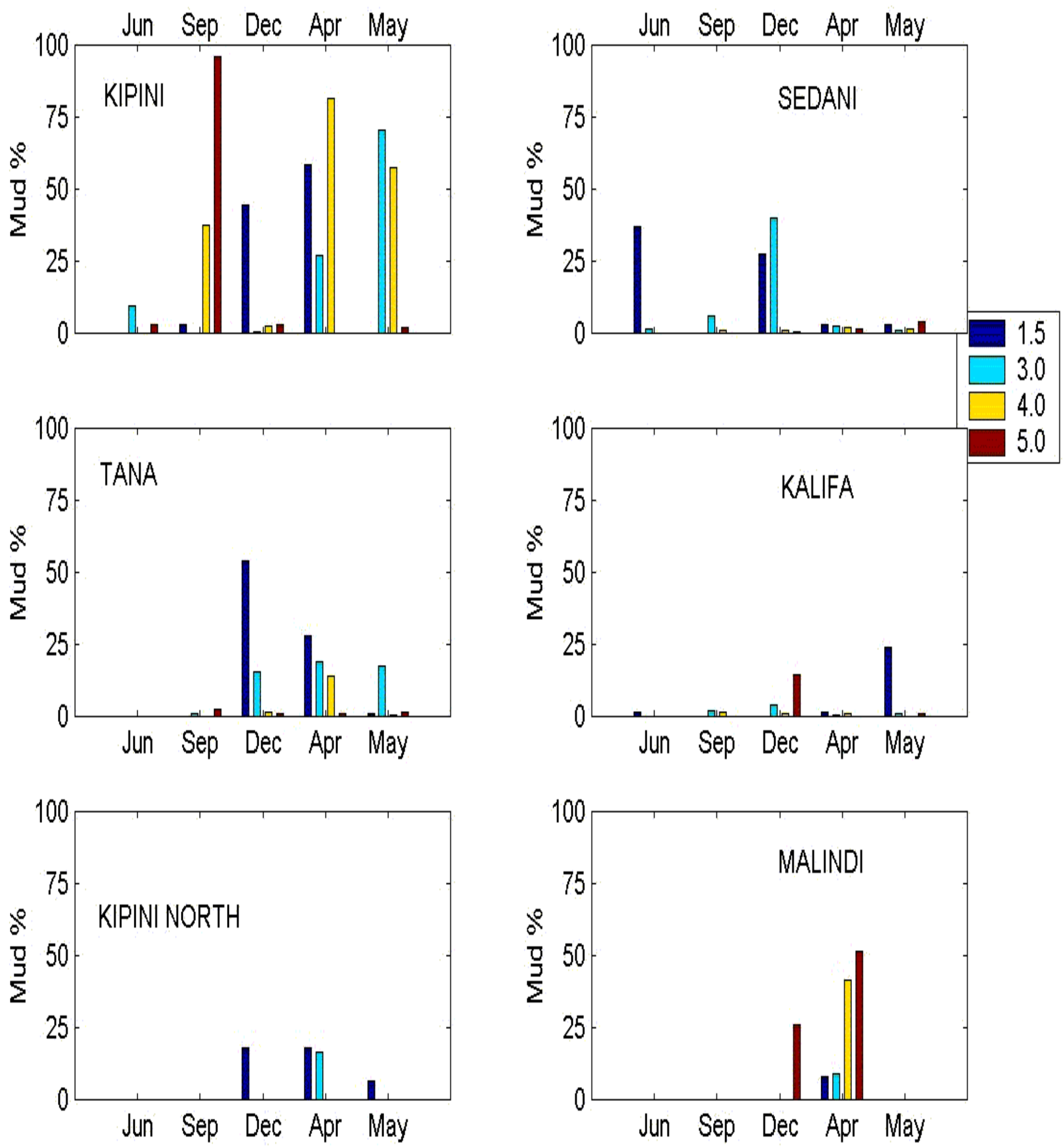


Fig. 2b. Sand content

The graph presents sand content observed in all the localities during the strategic sampling. High sand content is observed in all localities.

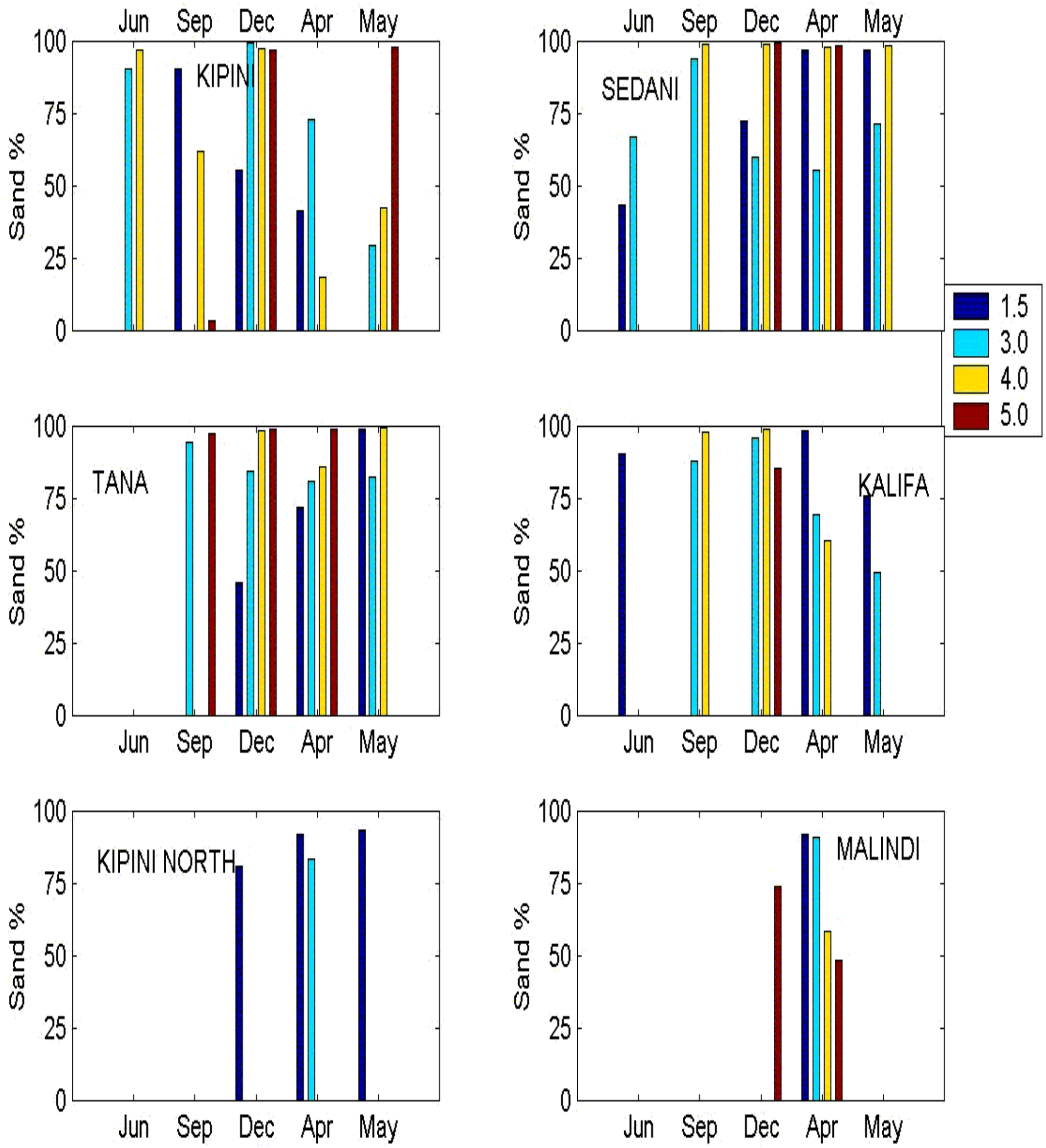


Fig. 2c. Gravel content

In the Kipini – Malindi area during strategic sampling. Gravels were observed in Sadani and Kalifi in localized areas.

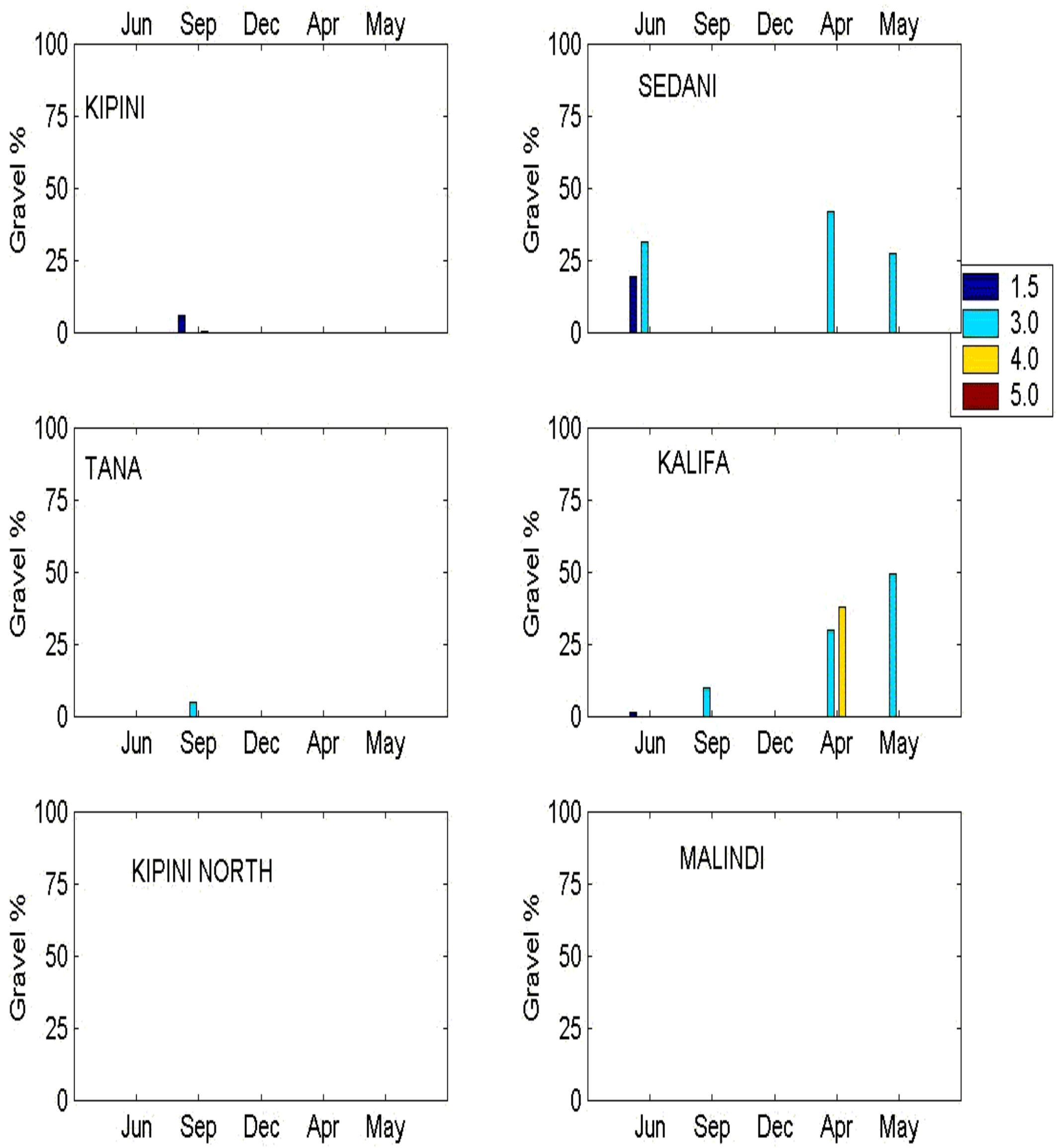
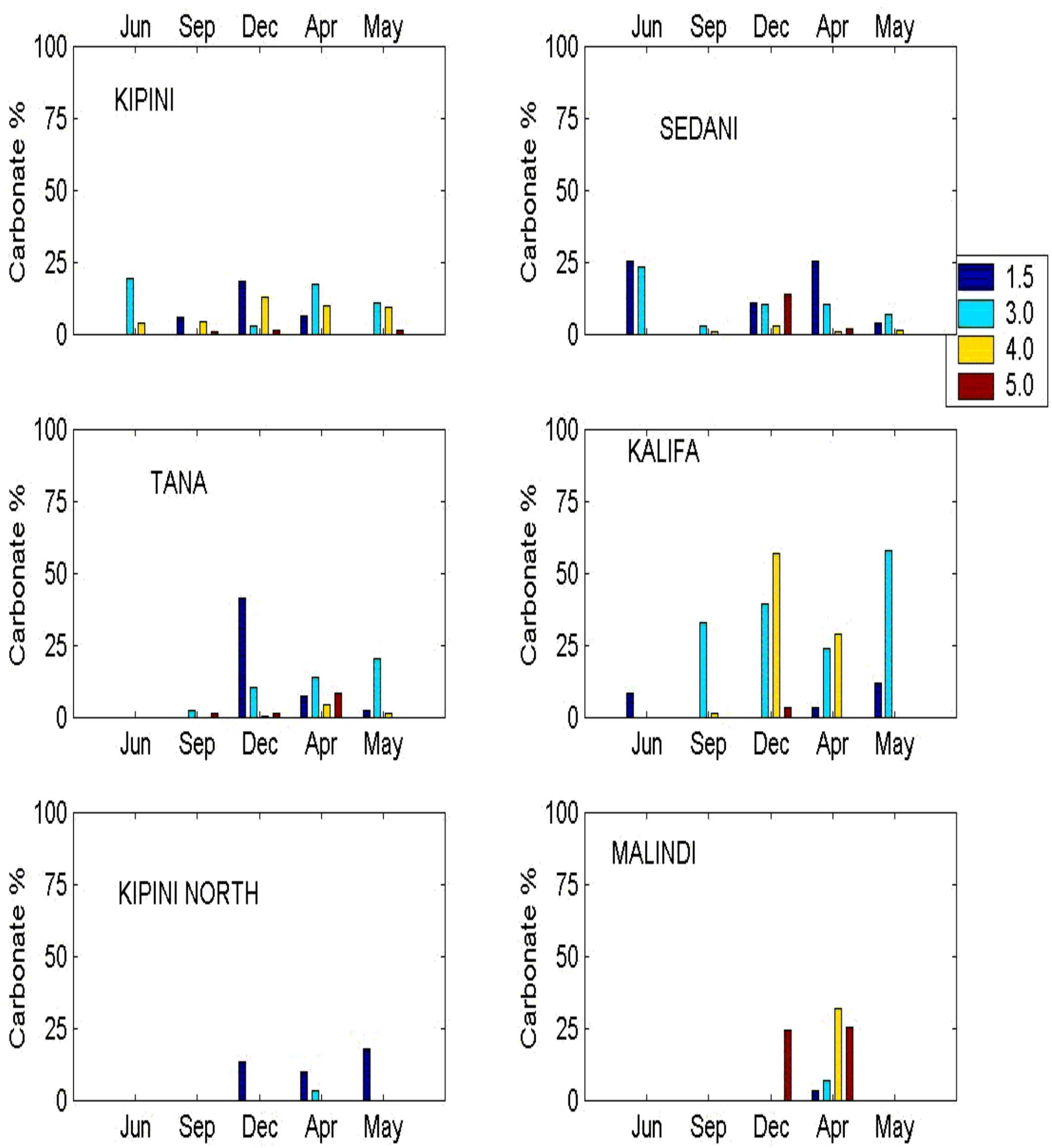


Fig. 2d.Carbonate content

Low carbonate percentage was observed at all stations indicating that the sediments are mainly land derived (terrigenous) from the Sabaki and Tana Rives.



DISCUSSION

The direct physical contact of fishing gear with the substratum can lead to the resuspension of sediments and the fragmentation of rock and biogenic substrata. The resuspension, transport and subsequent deposition of sediment may affect the settlement and feeding of the biota. Smothering of feeding ad respiratory organs. The quantity of sediment resuspended by trawling depends on sediment grain size and degree of sediment compaction, which is higher on mud and fine sand than on coarse sand. Given that bottom trawling can lead to large scale resuspension and transport of sediment it is reasonable to question whether fishing changes the particle size distribution or the internal structure of sediments. One might imagine, for example, that finer sediments would be washed out and transported further by water currents, leading to a gradual coarsening of medium sediment grain size.

CONCLUSION

Prawns are known to prefer muddy/silty environments. The bay is shallow and receives sediment input from the Tana and Sabaki rivers. Within Ungwana bay, prawn fisheries do well at 1.5 and 3.0 nautical miles. This correlates well with distribution of muddy substrate. At Kipini, prawn fisheries does well upto 5.0 nautical miles. This correlates well with the distribution of the muddy substrate.

The continental shelf is wider in Kipini – Kalifi area where it attains a width of 20 - 30 km, with depths of less than 20 m. However, at Mambrui and Sabaki the shelf drastically decreases to a distance of 5-10 km and the depth doubles to 40 m. The bottom topography of the bay has not changed much between 1984 and 1993. The highest rate of sedimentation and erosion has been recorded at Kipini and Mambrui to be +1.4 $myear^{-1}$ and –2.0 $myear^{-1}$ respectively.

Acknowledgements

I wish to thank all the members of the Ungwana bay team for their much co-operation and suggestions during the project period.

References

Kaiser M. J., Collie J. S., Hall S. J, Jennings S & Poiner I., 2002. Modification of Marine habitats by trawling activities: prognosis and solutions. In Fish and Fisheries 2002. Vol 3. Pp 114 – 136.

Hall G.P.D., Haslam D. W. & Owen H. M., 1984. Admiralty chart of Malindi to Ras Chiambone no. 3362. First published in 1957. Printed by London Admiralty, UK.

Hall G.P.D., Haslam D. W. & Owen H. M., 1993. Admiralty chart of Malindi to Ras Chiambone no. 3362. First published in 1957. Printed by London Admiralty, UK.

WATER QUALITY AND PRODUCTIVITY OF THE MALINDI-UNGWANA BAY FISHING GROUNDS

Stephen N. Mwangi

INTRODUCTION

The Malindi-Ungwana Bay fishing grounds are highly productive and provide a good fishery. The area is directly influenced by both natural and anthropogenic forces. This study was initiated to investigate the extent to which the environment of Malindi-Ungwana bay fishing grounds is influenced by land-based activities and trawling especially in relation to water quality, system health and functioning.

OBJECTIVES OF THE STUDY

The aim of the study was to determine various environmental and ecological factors that influence the distribution and viability of Malindi-Ungwana Bay fisheries. The factors evaluated included the determination of:

- dissolved inorganic nutrients and chlorophyll-a levels as indicators of productivity
- total organic material, particulate organic carbon (POC) and biological oxygen demand (BOD) as indicators of organic content of the water
- microbiological quality of water and seafood

RESEARCH METHODS

Study area, research strategy and methods

The study area extends from Ras Ngomeni to Ras Shaka (north of Kipini) in the northern banks of the Kenya coast to the Malindi-Mambrui area that is to the southern part of the bay**).** The study was conducted between June 2001 and May 2002. Representative sampling sites were chosen within the Malindi-Ungwana Bay area. Sampling was carried out aboard trawling vessels. The sampling programme was divided into monitoring and strategic sampling sessions. The monitoring programme involved boarding the trawling vessels every month and sampling in places where trawlers conduct their normal fishing activities. This was followed by strategic research programme involving sampling at designated sites from the shore seaward upto 5 nautical miles (figure 1). The sampling period was spread so as to include the north east (NE) and south east (SE) monsoon seasons. Water samples were collected using Niskin bottles and a grab sampler was used to collect sediment samples. The samples were immediately frozen onboard and transferred to KMFRI laboratories for analysis within 48 hours of arrival. Water transparency, suspended particulate material (SPM), particulate organic material (POM), particulate organic carbon (POC), biological oxygen demand (BOD), dissolved oxygen (DO), dissolved inorganic nutrients and chlorophyll-a were determined according to Parsons *et al.* (1984). As an indicator of microbiological pollution, faecal coliforms and *E. coli* were enumerated according to UNEP/WHO/IAEA (1985a, b).

RESULTS

Water transparency and suspended particulate matter

Figure 2 shows a typical trend of water transparency recorded in the Malindi-Ungwana Bay area while figure 3 is a representation of the concentration of suspended particulate material (SPM). There was a general increase in water transparency (i.e. decreasing turbidity) from the shore seawards. Figure 4 is a GIS map showing the general distribution of suspended particulate material (SPM) in Ungwana Bay area over the study period. From this map, it is indicated that there was a concentration of suspended materials nearer to the shore. The composition of water in terms of phytoplankton, dissolved substances and suspended particles contribute to the colour of the water.

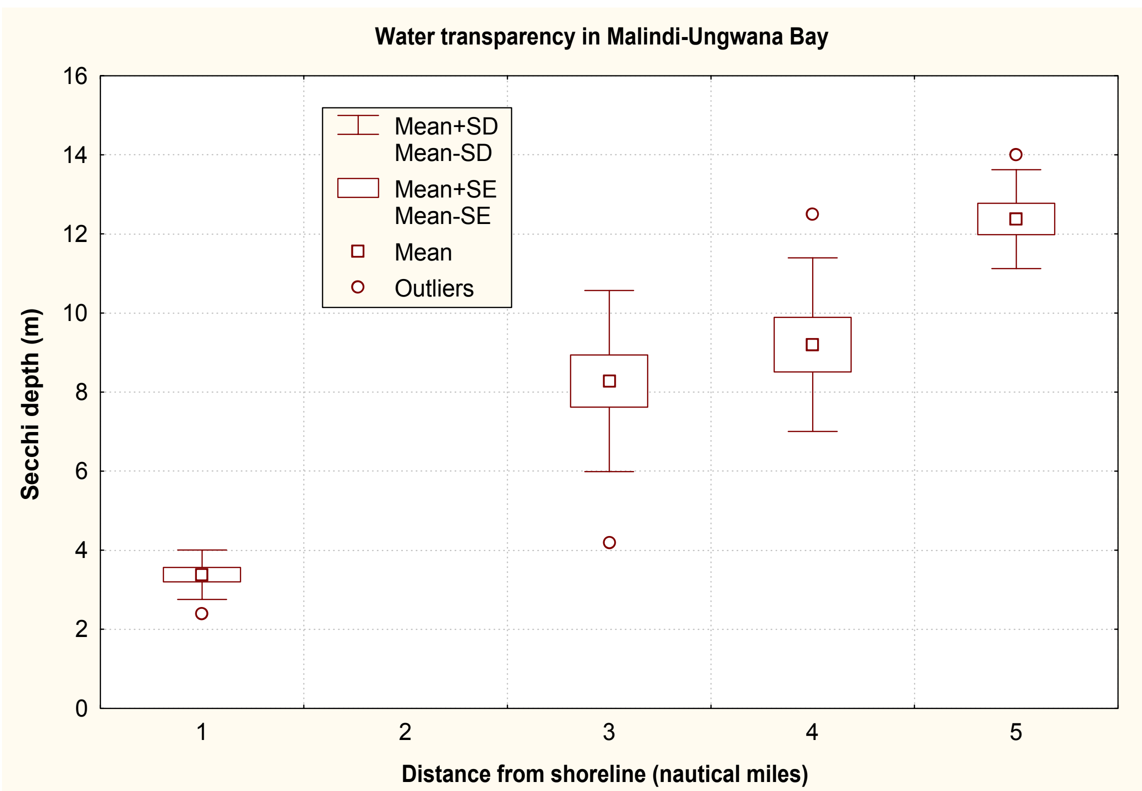
Particulate Organic Matter (POM), Particulate Organic Carbon (POC) and Biological Oxygen Demand (BOD)

The distribution of particulate organic matter (POM) in the area is related to that of suspended particulate matter and, as observed with SPM, POM concentration was higher nearer to the shore than in other areas. In general, higher POM concentrations were recorded between Tana and Sadani areas (figure 5). A summary of mean concentrations of SPM, POM, particulate organic carbon (POC) and biological oxygen demand (BOD) is shown in the table 1. Analysis of the results shows that within the 5 nautical miles area, there was no significant statistical difference in POM. Similarly, though there were some differences in the concentration of POM in the study area, there were no statistically significant differences in POM concentration among the different fishing grounds or seasons. In general, POM accounted for 15-20% of SPM with high values recorded seawards. Like POM, POC was variable within the study area. However, no statistical differences were found in POC concentration either among the fishing grounds, distance offshore or by season. An average of 1.2 (±2.4) mgl^{-1} POC was recorded in the study area. High BOD values were recorded in the whole fishing ground. Relatively high values recorded within the 2 nautical mile band. The overall mean BOD was 2.7(± 1.5) mgl^{-1} with the highest BOD levels recorded in Malindi-Mambrui and Kipini areas with BOD of upto 6.5 mgl^{-1} recorded in Mambrui area.

Table 1. *Mean levels of SPM, POM, POC and BOD (± SD) in Malindi-Ungwana Bay*

	Mambrui	Kalifi	Tana	Sadani	Kipini	All Areas
SPM (mgl^{-1})	**21.9** (±8.2)	**26.6** (±7.5)	**28.7** (±17.6)	**25.2** (±7.9)	**36.4** (±17.6)	**28.4** (±13.3)
POM (mgl^{-1})	**4.1** (±4.2)	**7.0** (±17.2)	**3.3** (±3.2)	**4.3** (±3.1)	**4.1** (±4.2)	**4.5** (±7.6)
POC (mgl^{-1})	**1.1** (±1.6)	**1.1** (±1.3)	**0.9** (±0.7)	**0.8** (±0.5)	**1.0** (±0.7)	**1.2** (±2.4)
BOD (mgO_2l^{-1})	**3.2** (±1.7)	**2.5** (±1.1)	**2.4** (±1.9)	**2.4** (±1.2)	**2.9** (±1.2)	**2.7** (±1.5)

Figure 2. ***Typical seaward trend in water transparency in Malindi-Ungwana Bay***



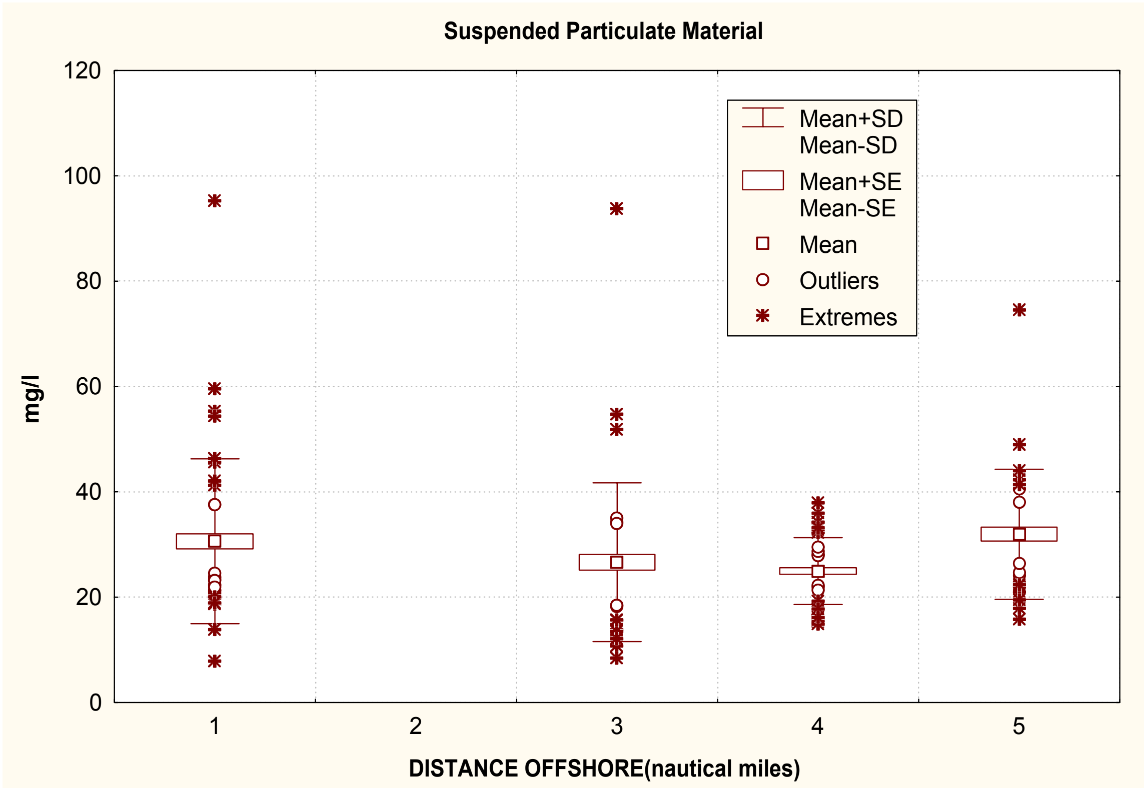


Figure 3. ***Suspended particulate material (SPM) in Malindi-Ungwana Bay***

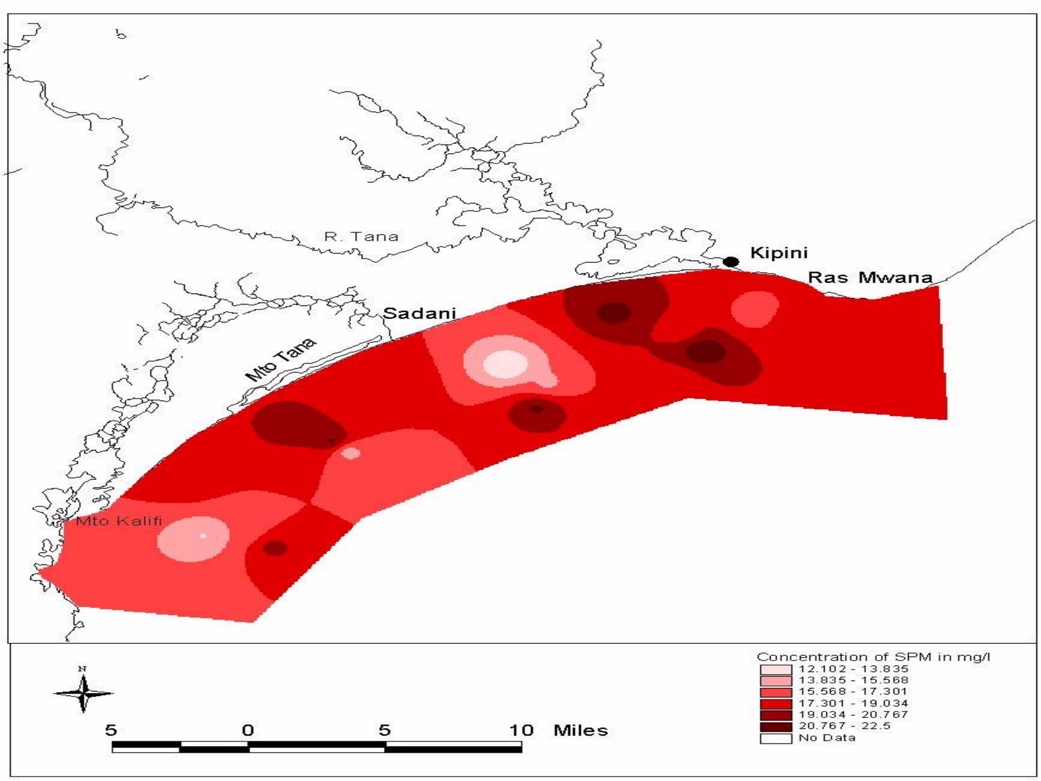


Figure 4: Suspended particulate material (SPM) in Ungwana Bay.

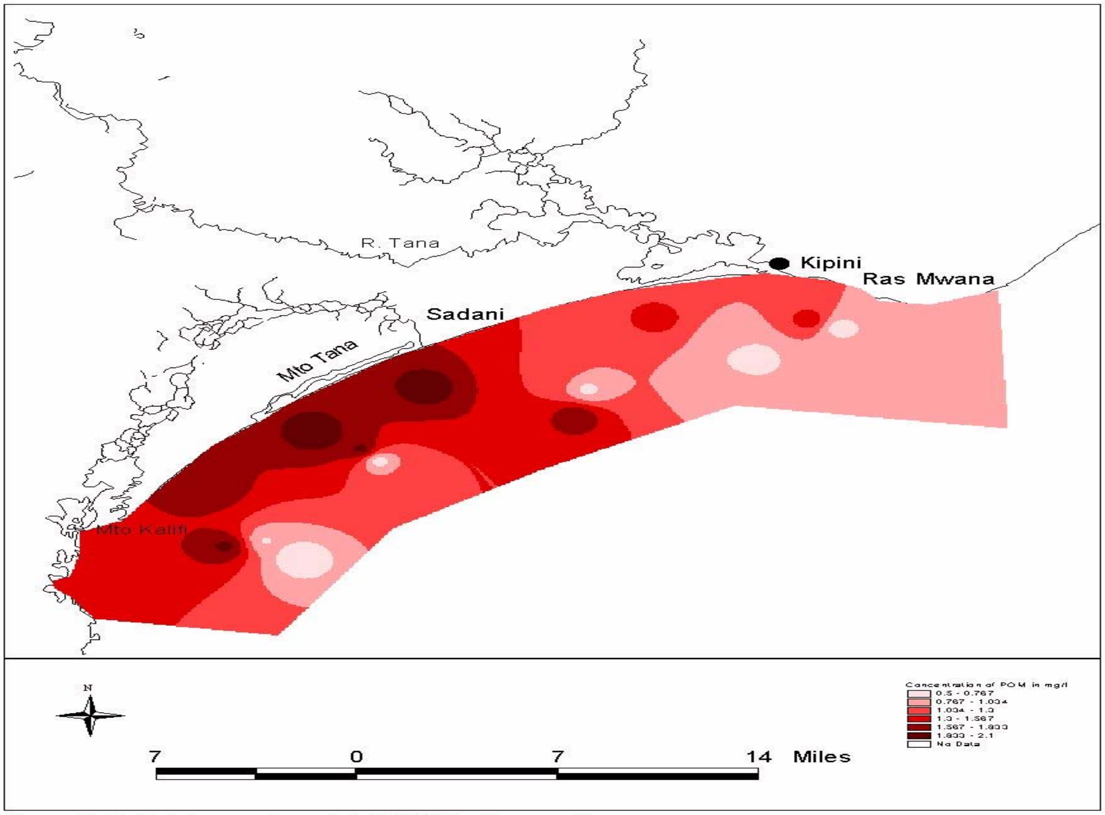


Figure 5: Particulate organic material (POM) in Ungwana Bay.

Dissolved oxygen

During the study period, there was variability of the amount of oxygen dissolved in water from the shore seawards (figure 6). Annual averages of 7.7 ($\pm$1.7) mgO_2l^{-1} and 10.2 ($\pm$0.6) mgO_2l^{-1} were recorded during the strategic and monitoring sampling cruises respectively. During the study period, high concentrations of dissolved oxygen of upto 15 mgO_2l^{-1}.were recorded. Oxygen saturation in the water of the Malindi-Ungwana Bay area always exceeded 75%.

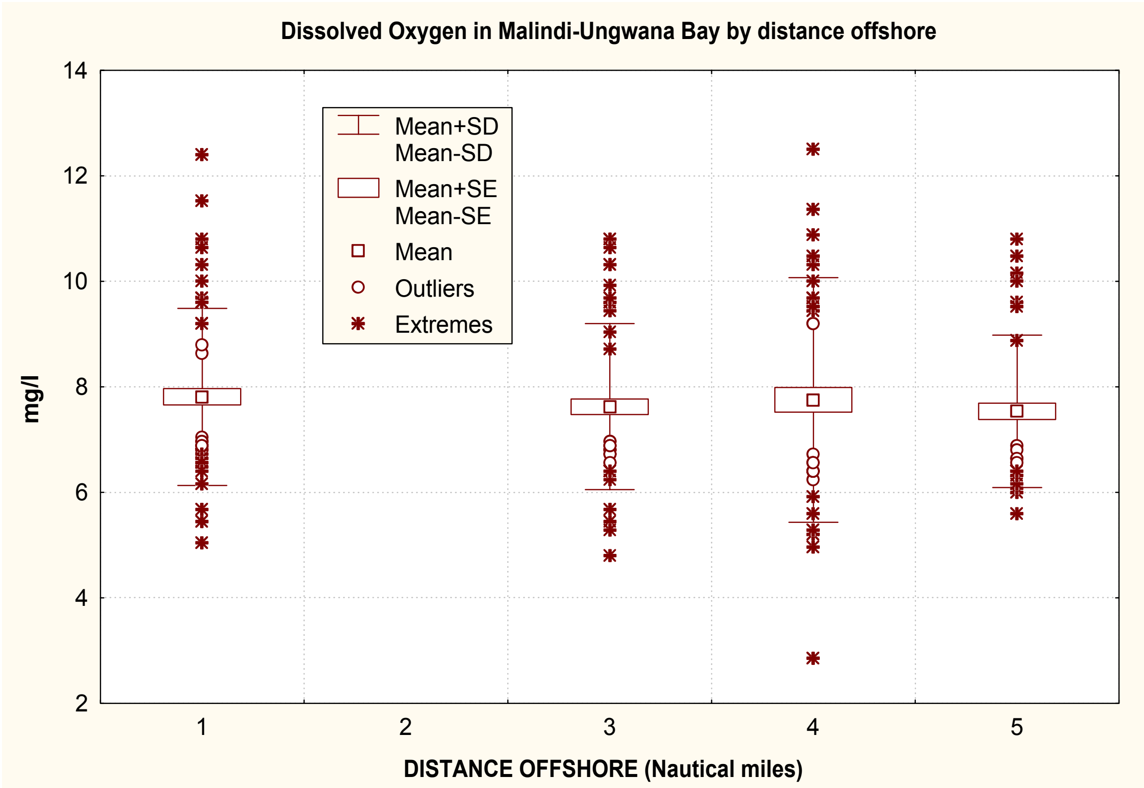


Fig. 6. *Spatial variation in oxygen concentration in Malindi-Ungwana Bay*

Nutrients

The concentrations of dissolved inorganic nutrients in the Malindi-Ungwana bay area were variable and related to the area, distance offshore and season.
Figure 7 and table 2 show seaward distribution of dissolved inorganic nutrients and Figure 8 and table 3 show the differences in inorganic nutrient concentration among the different trawling grounds (irrespective of the distance offshore).

Table 2. *Mean levels of dissolved inorganic nutrients (± SD) in Malindi-Ungwana Bay trawling grounds as a function of distance from shore seawards.*

	1.5 naut. miles	3 naut. miles	4 naut. miles	5 naut. miles
Ammonium (μM-N)	**6.2** (±10.9)	**5.5** (±10.3)	**5.0** (±6.7)	**3.9** (±4.5)
Nitrate+Nitrite (μM-N)	**1.4** (±0.8)	**1.5** (±0.7)	**1.5** (±0.7)	**1.0** (±0.4)
Phosphate (μM-P)	**1.1** (±1.7)	**1.0** (±1.6)	**0.6** (±0.5)	**0.7** (±0.7)

Table 3. *Mean levels of dissolved inorganic Nutrients and chlorophyll-a (± SD) in Malindi-Ungwana Bay trawling grounds.*

	Mambrui	**Kalifi**	**Tana**	**Sadani**	**Kipini**	**All Areas**
Ammonium (μM-N)	**10.3** (±15.0)	**3.0** (±2.8)	**4.2** (±9.6)	**5.4** (±7.3)	**4.1** (±4.6)	**5.3** (± 9.0)
Nitrate+Nitrite (μM-N)	**1.4** (±0.8)	**1.4** (±0.7)	**1.5** (±0.7)	**1.3** (±0.6)	**1.2** (±0.6)	**1.4** (±0.7)
Phosphate (μM-P)	**0.9** (±0.8)	**0.9** (±1.0)	**0.8** (±1.4)	**0.6** (±0.5)	**1.0** (±1.4)	**0.9** (±1.4)
Chlorophyll-a ($\mu g l^{-1}$)	**1.2** (±1.4)	**0.7** (±0.6)	**0.9** (±0.8)	**1.1** (±1.1)	**1.0** (±1.2)	**1.1** (±1.0)

During the study, higher nutrient concentrations (upto 74 μM ammonium-N, 6.0 μM nitrite + nitrate-N and 11.5 μM phosphate-P) were recorded during the intermonsoon period (April & May) and this coincided with the wet season.

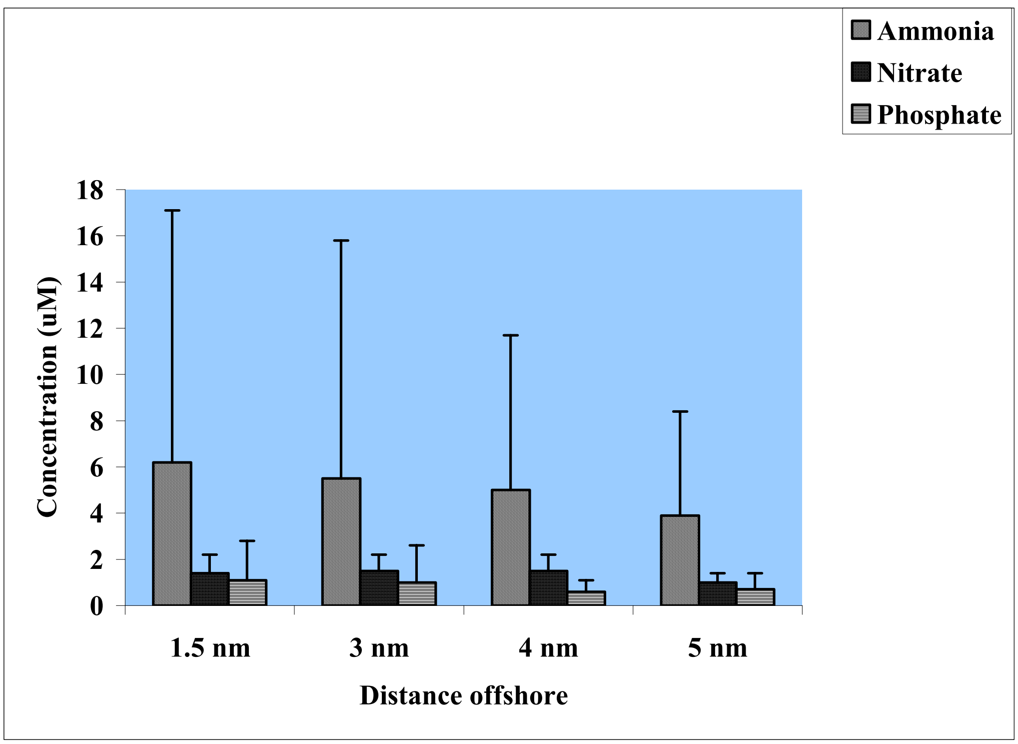


Figure 7. *Distribution of dissolved inorganic nutrients in Malindi-Ungwana*

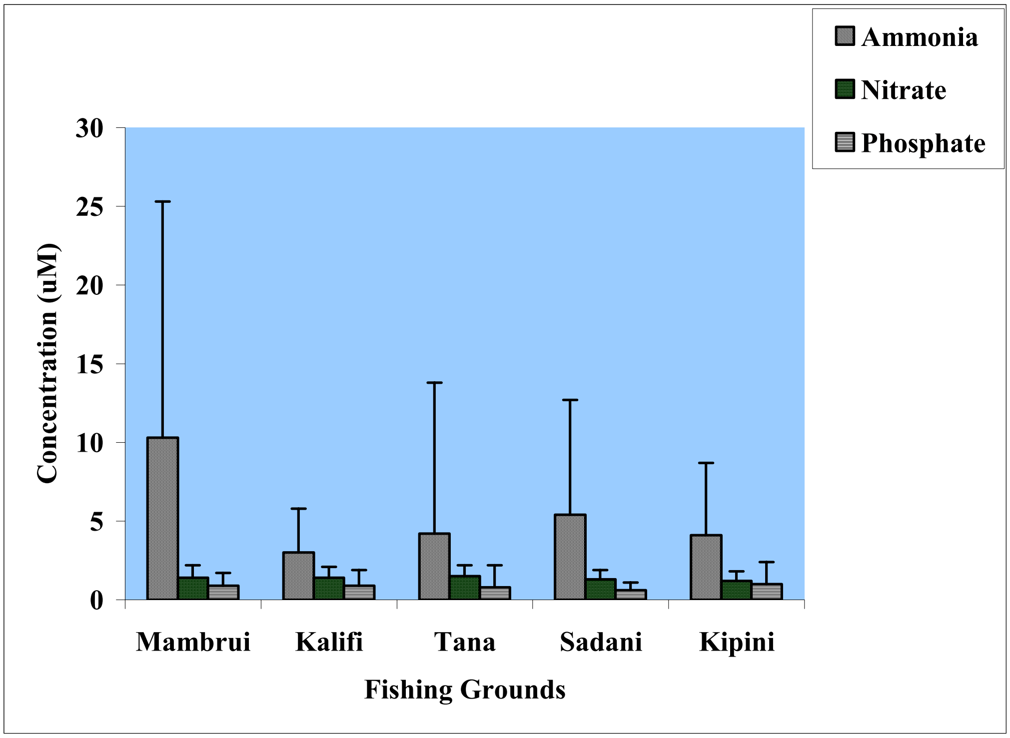


Figure 8*. Nutrient concentration in Malindi-Ungwana Bay (by trawling area)*

Chlorophyll-a

Analysis of results shows spatial and temporal variations in chlorophyll-a in the area. A mean of 1.4 (±2.0) μgl^{-1} chlorophyll-a was recorded in the Malindi-Ungwana Bay area. However, levels were higher in Ungwana Bay than in the Malindi-Mambrui area (about 1.1 μgl^{-1} and 1.5 μgl^{-1} respectively). No significant differences in chlorophyll-a were found among the trawling grounds or with distance offshore. However, chlorophyll-a levels recorded during wet season (April and May) were significantly higher than during the dry season (p=0.002)-figure 9. Figure 10 shows chlorophyll-a distribution in Ungwana Bay area (as a function of distance offshore) during the study period. The concentration of chlorophyll-a was high throughout the study area but higher chlorophyll-a levels were recorded within the 3 nautical mile transect. However, the differences were not statistically significant.

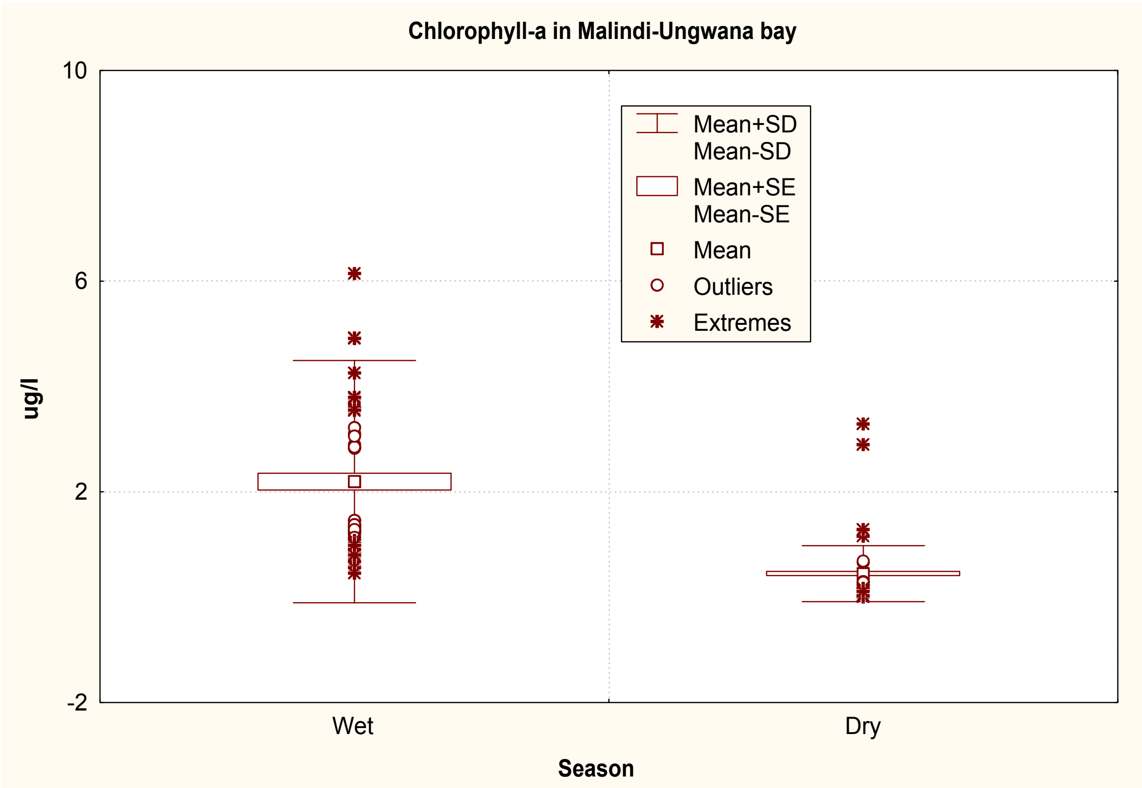


Figure 9. *Seasonal variation in chlorophyll-a concentration in Malindi-Ungwana Bay*

Mean chlorophyll-a in the Malindi-Ungwana Bay trawling grounds were higher than the overall mean monthly values of about 0.5 $\mu g l^{-1}$ observed in Diani,

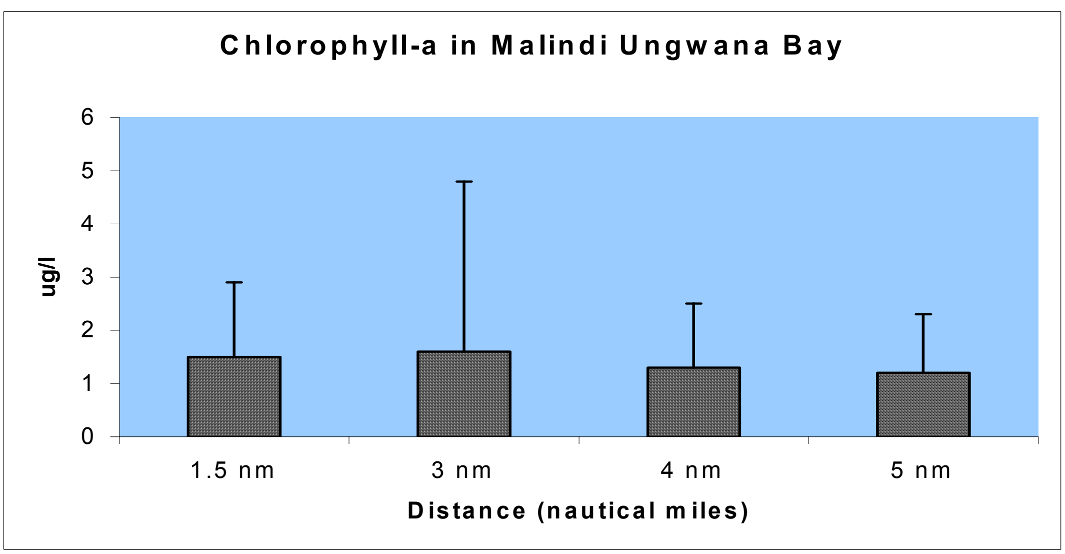


Figure 10. *Spatial variation in chlorophyll-a concentration in Malindi-Ungwana Bay.*

Bacterial Contamination

The number of faecal coliforms and *E. coli* recorded were low (table 4) and decreased from the shore seawards. Insignificant levels of these bacteria were present beyond the 3 nautical miles from the shore.

Table 4. *Faecal coliforms and E. coli recorded in water samples within the 3 nautical mile band in the study area.*

Area	Faecal coliforms (no/100ml)	*E. coli* (no/100ml)
Malindi-Mambrui	**16** ±2.8	**3** ± 1.4
Kalifi	**12** ± 0.7	**2** ± 2.8
Tana	**10** ± 1.4	**3** ±1.4
Sadani	**13** ±2.1	**4** ±1.4
Kipini	**19** ± 2.8	**4** ± 1.4

Though the Malindi-Mambrui and Kipini areas seemed to have relatively higher faecal coliforms and *E. coli* counts, the levels of these indicators of microbiological pollution were low (below 20 faecal coliforms and below 5 *E. coli* per 100 millilitres water sample). In fish and prawns harvested in this area, less than 3 faecal coliforms and no *E. coli* per gram of the fresh were recorded.

DISCUSSION

Ungwana Bay can be described as a shallow relatively turbid environment with strong hydrodynamic forcing. There is biologically and chemically mediated physical aggregation of particles that include debris of macroalgae and vascular plants (especially mangroves), phytoplankton, faecal pellets and inorganic particles. These are not only from the water column but are also resuspended from sediments. The suspended materials are of high organic content (as indicated by high percentage of POM) with high carbon content. The high BOD levels (upto 6.5 mgl^{-1}) in the area is a clear indication that most of organic material in the area are easily degradable thus easily available to the organisms in the system. The area is rich in organic matter and has relatively high BOD (comparable to levels in creek waters along the Kenya coast). However, the hydrodynamic settings ensure good flushing such that the Malindi-Ungwana Bay waters are rich in dissolved oxygen for organic material oxidation and also ensures that surface sediments are not anoxic.

The nutrient levels recorded within the Malindi-Ungwana Bay study area are relatively high for oceanic waters and are comparable to levels reported in Diani and Kinondo/Galu areas where there is groundwater flow (Uku, 1995). Nutrient levels recorded in this study are lower than those recorded in river Sabaki estuary where there is a distinct seasonality in nutrient fluxes from river Sabaki. In the Sabaki area nitrate concentrations were as high as 97.12 μM-N and 0.01 μM-N for the rainy and dry seasons respectively (Ohowa, 1996). The concentrations in this study are comparable to levels recorded in creek waters along Kenya coast (Ohowa *et al.,* 1997, Kazungu *et al.,* 1989, Kazungu, 1996, Mwangi, 1994, Mwangi *et al*., 1998, Kitheka *et al* 1996, Kasyi, 1993). However, ammonium levels especially within Malindi-Mambrui area were very high and suggests that the Sabaki river is an important source of nutrients for the estuarine and shallow areas of the Malindi-Mambrui fishing grounds. Nutrient concentration is strongly influenced by river input, terrestrial runoffs and resuspension processes in the shallow area. Breakdown of organic materials initially yields a high ammonium concentration. Due to the high oxygen concentration in the water column and surface sediments, excess ammonium is oxidised to nitrite and nitrate. The availability of nutrients and light penetration down to the bottom of the area ensures that both pelagic (water column) and benthic phytoplankton are able to photosynthesize.

High chlorophyll-a values recorded in the area therefore indicate a high phytoplankton biomass. This is also an indication that the turbidity in this area is not so high as to seriously affect light penetration into the water column. High nutrient, organic matter and phytoplankton biomass especially during the wet seasons create a good environment for prawn, crab and fish larvae that are abundant during these periods (see separate report by Mwaluma).

Microbiological quality

Water quality guidelines provide with the limit for contaminants with respect to both protection of aquatic ecosystems and for the health of humans in terms of biota, human food and recreational use. Faecal coliforms are indicators of human health risk. Concentrations of faecal coliforms and *E. coli* are elevated in areas receiving undisinfected sewage effluent or animal waste. During this study, less than 50 faecal coliforms and 10 *Escherichia coli* per 100 millilitres of water were recorded. This implies that there is no serious microbial contamination in the area and that water quality in Malindi- Ungwana Bay conforms to EEC guidelimits. Obviously, Sabaki and Tana rivers receive direct sewage input at one point or the other along the catchment areas. However, through self-purification processes, the bacterial load in the river waters decreases as a result of bacteria die offs. Additionally, the antiseptic properties of seawater further decreases the bacterial concentration once the freshwater mixes with marine waters.

CONCLUSION

Though there is variation in levels of nutrients, chlorophyll-a, suspended particulate material and organic matter in Ungwana Bay, the area can be classified as a shallow nutrient rich productive area with easily degradable organic material that is available for both suspension and benthic feeders. There is also a high organic matter content in the muddy sediments especially within the 3 nautical mile band. These shallow environments between the shore and 6 nautical miles are important in sustaining the prawn fishery in the area.

Shallowness and width of Ungwana bay area and the riverine inputs are responsible for the variable and seasonal changes in the physico-chemical parameters investigated in this study. In Ungwana Bay, the factors contributing to water and sediment qualities (thus productivity) are riverine input from the Tana River delta discharge, terrestrial runoff, trawling activities and oceanic processes. The bathymetry, hydrodynamic settings and trawling activities ensure mixing of the water column and resuspension and churning of organic rich sediments thus ensuring almost uniform distribution of the physico-chemical characteristics of the area. In the Malindi-Mambrui area, Sabaki River has a significant influence on the water and sediment quality. Sediments from the river are rich in organic material and through mineralisation processes, the sediments act as a source of nutrients.

Though the rivers discharging into Malindi-Ungwana Bay areas have large catchment areas and are expected to contaminate the marine environment, there was is no evidence of serious microbiological (bacterial) contamination of the fishing grounds. This is an indication that the area is safe for fishing and the seafood harvested from the area is safe for human consumption.

Acknowledgement

I acknowledge the active contribution of Charles Mitto, Patrick Mathendu, Charles Muthama, Joseph Kilonzi and James Emuria for their involvement in field activities, sample analysis and technical support. KMFRI institutional and financial support is highly appreciated. I also acknowledge the crew of Alpha group of companies and Basta & Sons (fishing companies) for cooperation and support.

References

Kasyi, J. N. (1993). Relationship between nutrient levels, phytoplankton biomass, zooplankton composition and abundance in the Tudor Creek Mombasa, Kenya. Msc thesis. University of Nairobi. 112pp.

Kazungu J. M., Dehairs F., Goeyens L. (1989). Nutrient distribution patterns in Tudor estuary (Mombasa, Kenya) during rainy season. Kenya Journal of Science Series (B). 10. 47-61.

Kazungu, J.M. 1996. Nitrogen-transformation processes in a tropical mangrove ecosystem (Gazi Bay, Kenya). PhD thesis . Vrije Universiteit Brussel, Belgium.198pp.

Mwangi S. (1994). The influence of bivalve filter feeders on bacterial populations and seston in Gazi Bay and Wadden Sea. Msc thesis University of Brussels, Belgium.

Mwangi S. Kirugara D., Osore M. Njoya J., yobe A., Dzeha T. (1998). Status of marine pollution in Mombasa marine park, reserve and Mtwapa Creek, Kenya. Technical report.

Parsons, T.R., Maita Y. & Lalli C.M. (1984). A manual of chemical and biological methods for seawater analysis. Pergamon Press. 173pp.

Ohowa B.O. (1996). Seasonal variation of nutrient fluxes into the Indian Ocean from the river Sabaki, Kenya.Discov. Innov. 8 (3):265-274

Ohowa B.O., Mwashote BM., Shimbira W. S.(1997). Dissolved inorganic nutrient fluxes from two seasonal rivers in Gazi Bay, Kenya. Estuarine , Coastal and Shelf Science. 45, 189-195.

Uku, J. N. (1995). An ecological assessment of littoral seagrass communities in Diani and Galu coastal beaches, Kenya. Msc thesis. University of Nairobi. 200pp.

UNEP/WHO/IAEA (1985a). The determination of faecal coliforms in sea water by the multiple test tube (MPN) method. Reference methods for marine pollution studies No. 22 (draft). 23pp.

UNEP/WHO/IAEA (1985b). The determination of Faecal streptococci in sea water by the multiple test tube (MPN) method. Reference methods for marine pollution studies No. 23 (draft) 21pp.

CHAPTER 2: THE MALINDI-UNGWANA BAY FISHERY

ASSESSMENT OF THE PRAWN FISHERY, BYCATCH, RESOURCE USE CONFLICTS AND PERFORMANCE OF THE TURTLE EXCLUDER DEVICE

Gerald K. Mwatha

INTRODUCTION

Artisanal fishing is confined to the shallow waters along the entire coastline. The artisanal fishery accounts for about 90% of the annual total marine fish landed about 10,000 metric tons. The catch is mostly made up of the fish families Scaridae, Siganidae, Nemipteridae, Lethrinidae and Lutjanidae. On the other hand, semi-industrial trawlers target the shallow water prawns and land on average around 400 metric tons annually (Anon 2001). The semi-industrial prawn fishing is restricted to the Malindi-Ungwana bay where suitable trawling grounds exist. Relative to the other parts of the Kenyan coastline, Ungwana bay has the widest continental shelf.

The existence of the shallow water penaeid shrimps fishery in the Malindi-Ungwana bay was established during a survey undertaken by various fishing expeditions in the 1960's and 70's. The expeditions were carried out by the Kenya Government with assistance from UNDP and FAO. It was established that a reasonably equipped prawn trawler could land as much as 3 to 4 tones of marketable crustacean per day. According to Mutagyera (1984), good trawling grounds exists in the Malindi-Ungwana bay in shallow waters less than 30 meters. The area available for trawling of shallow water penaeid prawns in this area is about 350 Nm^2. Semi-industrial prawn trawling has been going on in the area for the last three decades. The number of licensed vessels, licensed by the fishery has fluctuated between 4 and 20.

Major issues of concern on this fishery include open access to the resources and lack of information on exploitation especially the maximum sustainable level for the fishery. The limited monitoring undertaken is not adequate to assess the state of the resource and to determine the negative effects, which trawling may have had on the other resources and the environment. Communities living at the vicinity of the trawling grounds have over the years complained about the negative impacts of trawling on the resources and their livelihood. To address this concern, a stakeholders meeting was convened in November 2000 to seek for a lasting solution to the existing conflicts. The stakeholders consultative meeting identified several issues that needed urgent attention.

Issues Raised at the Consultative Meeting

The issues raised included;

- Resource use conflicts
- High levels of artisanal fishermen gear destruction by the trawlers
- High levels of bycatch and discards within the semi-industrial trawl fishery
- Habitat destruction by the bottom trawls
- Declining fishermen catches within the Malindi-Ungwana bay area
- Pollution concerns
- Lack of data/information on the current state of the fish stocks (finfish/prawn).
- Contravention of the Fisheries Act by prawn trawlers.

It was agreed that KMFRI undertakes a one year research to address the identified issues.

The Research programme adopted the following objectives a key to answer to the questions raised by the stakeholders.

RESEARCH OBJECTIVES

(i) To determine fishing sites of prawn trawlers.
(ii) To determine the abundance and distribution of prawn stocks.
(iii) To determine the abundance and distribution of other fishes.
(iv) To carry out an assessment of the quality and quantity of trawling bycatch and discards.
(v) To determine TED use efficiency and compliance.

STUDY AREA

Lies between latitudes $3^{0}30'$S and $2^{0}30'$S and longitudes $40^{0}00'$N and $41^{0}00$N covering the Malindi and Ungwana (fig 1). The Malindi-Ugwana bay complex has a wide continental shelf with simple trolling grounds. The river Tana and Sabaki drain fresh water and sediments into the bay especially during April and June that coincide with the long rains.

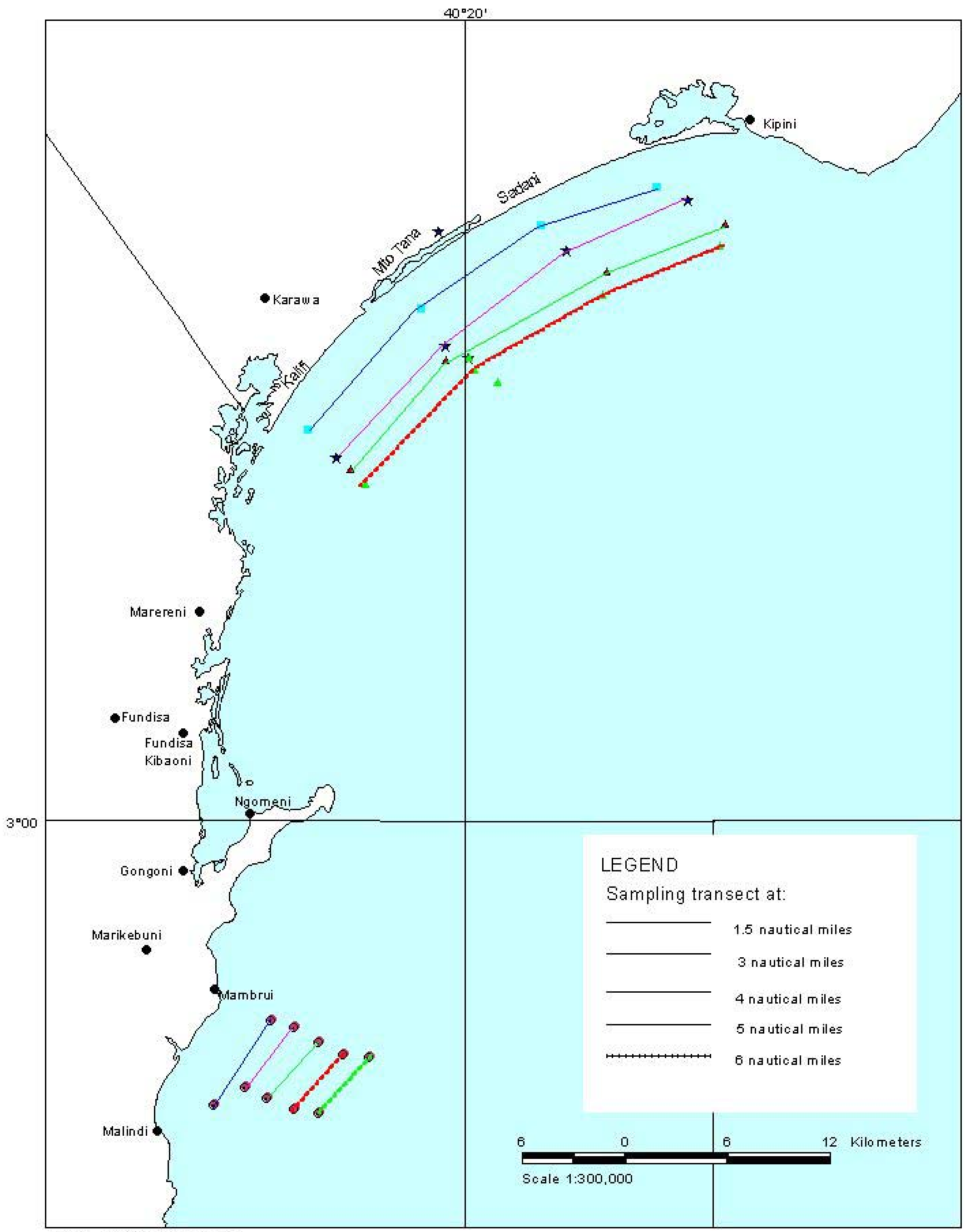


Fig.1. The study area

RESEARCH METHODS

The survey was carried out using the four licensed private prawn trawlers MV Alpha Manyara, Amboseli and Serengeti. These vessels are 25 meters long with an engine capacity of 624 horse power. MV Venture II; is 36 meters long and is powered by a 935 horse power engine. Fishing was carried out using beam bottom trawls. Appendix 1.

Field data collection

From May 2001 to May 2002, research teams randomly boarded the prawn trawlers. Two data collection strategies were adopted in the study. In the first strategy the skipper was allowed to undertake normal commercial fishing. The gear used, area fished and period fished solely depended on the skipper's choice. Each monitoring trip lasted six days. Every three months a designed research cruise was undertaken. During these cruises predetermined and well defined transects (fixed using a GPS) were sampled. The transects were located at 1.5, 3, 4, 5 and 6 nautical miles from the shore in both Malindi and Ungwana Bay fishing grounds (Fig.1). The fishing site, time and occasionally the gear used were determined by the research personnel. Fishing was carried out during the day between 6 a.m. and 6 p.m. for both cruises.

The catch composition

Each catch haul was differentiated into four broad categories, Prawns, Retained bycatch, Discards, and Large organisms e.g. Sharks and rays. Depending on the size of the catch, the whole or part of the catch was sorted into species. Size of every fish (TL) and its carapace length was measured and weight determined. The same procedure was repeated for sub samples taken after thorough mixing. The total weight of discards and bycatch was determined. The larger organisms (sharks and rays, turtles etc) were measured and weighed separately.

RESULTS

In the last ten years a gradual increase in the total annual fish landings was observed in Kipini. Total fish landings in various landing sites in Malindi district have shown a gradual decline over the same period (Figure 3). Gradual decline in catches is observed in Malindi, Mayungu and Watamu whereas a substantial increase in catches is evident in Ngomeni in the year 2000. Landings increased overall from 200 tons in 1999 to 330 tons for the year 2000.

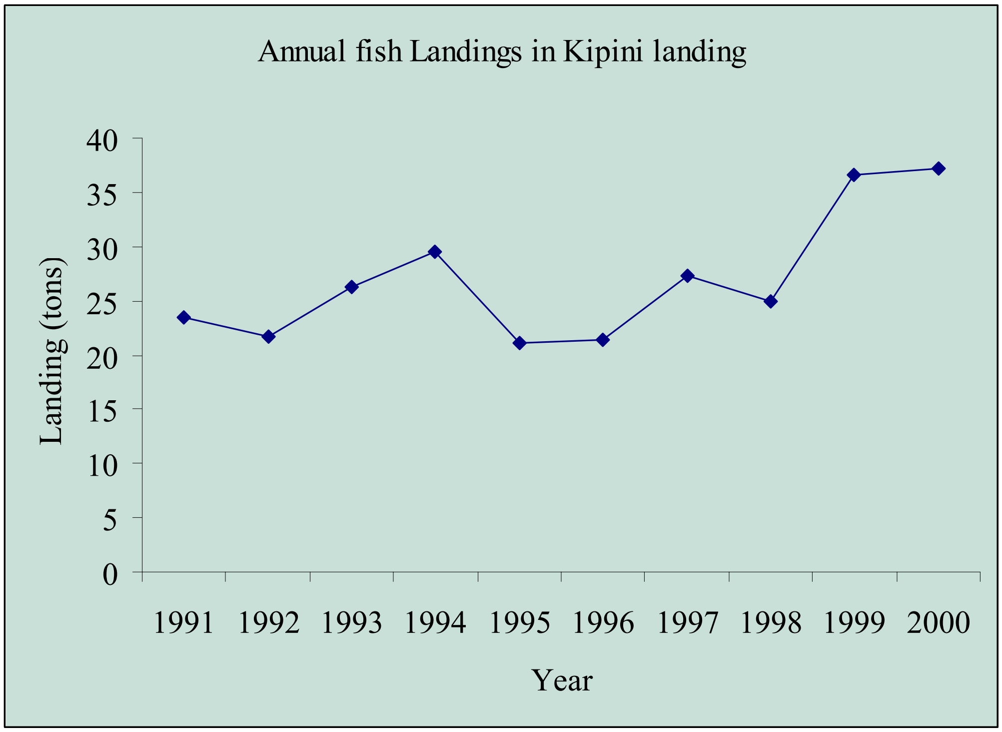


Figure 1. The annual fish landings in Kipini (Data courtesy of Fisheries Dept.)

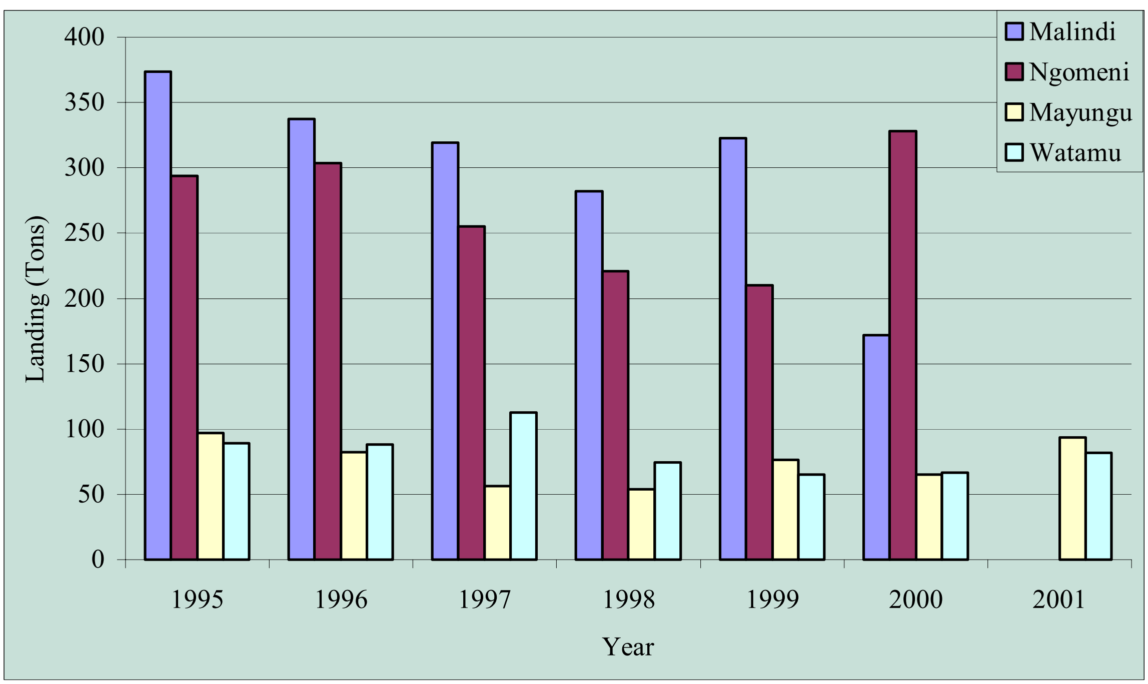


Figure 2. The annual fishing landings from the landing site within Malindi district (Data courtesy of Fisheries Dept.)

PERFORMANCE OF THE SEMI-COMMERCIAL TRAWL FISHERY

Figure 4 shows the total landings from semi-industrial prawn trawlers. Total landings for prawns have fluctuated between 664 to 306 tons with the retained bycatch fluctuating between 91 and 475 tons. The catch per unit effort (Fig.5) fluctuated between 60 and 120 tons per trawler per year over the same period with a peak of 100 to 120 tons observed in 1998 and 2001 respectively (Fig 5). This corresponds well with the trend of the total landings witnessed over the same period.

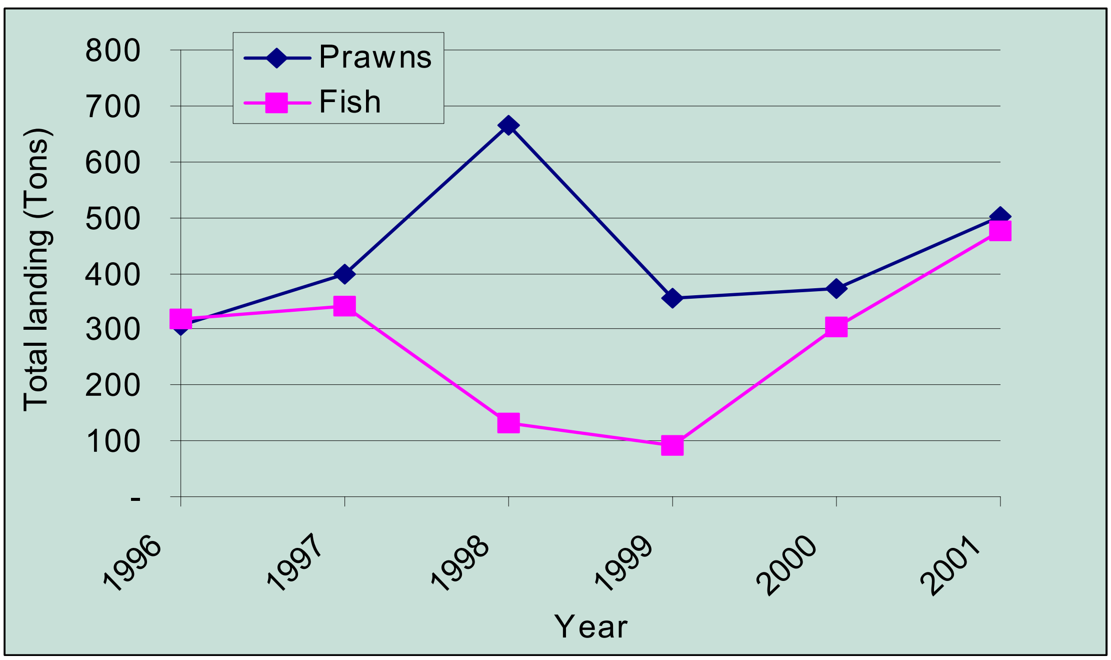


Figure 3. Annual landing of prawns and fish by the semi- industrial prawn trawlers operating in Malindi – Ungwana bay area (Data courtesy of SECO and Alpha fishing companies).

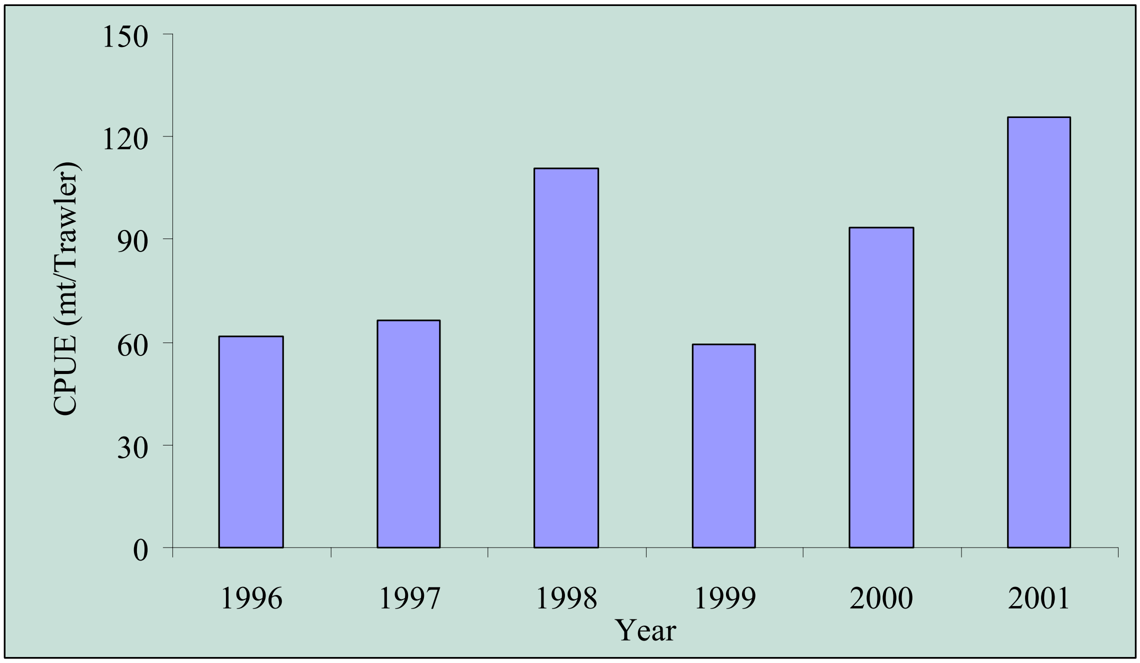


Figure 4. Annual catch per unit effort of the semi- industrial trawling industry in Malindi- Ungwana bay.

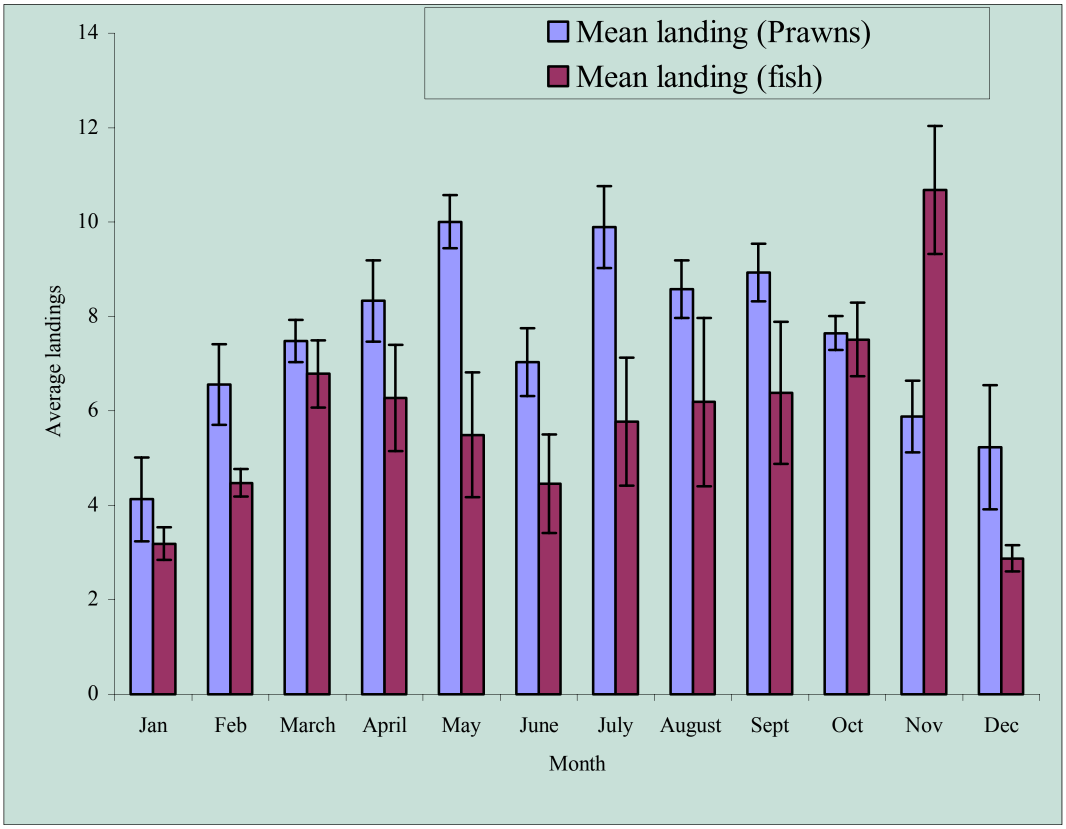


Figure 5. The mean landings of fish and prawns by the semi- industrial fishery in the Malindi – Ungwana bay area.

The monthly mean landings of prawns and fish from semi-industrial prawn fishery from 1996 to 2001 is shown in (Fig.6). High prawn landings are recorded during the SE Monsoon (April and September) with a slight decrease in June. Low prawn landings are evident during the NE Monsoon (October-February). This shows a clear seasonality pattern.

FISHING OPERATIONS AND FISHING SITES

Nets are dragged at an average speed of 3 knots for a period ranging between one and half to three and half hours. A small trawl net, normally called a test net is dragged together with the main nets. The test net is hauled in every thirty minutes, to check the bottom and the concentrations of prawns. The mean trawling period is normally two hours. On average, the trawlers make four hauls per day.

It was noticed that the trawlers preferred fishing between 0.8 to 3 nautical miles. It was also observed that the trawlers tended to concentrate in selected areas as long as the prawn catches were good. The most visited areas are off River Sabaki, Sandani and Kipini.

SPATIAL AND TEMPORAL DISTRIBUTION PATTERNS OF PRAWNS

Spatial distribution of prawns for the whole area decreased with distance from the shore (Fig.7) except in April and May when prawns were distributed in all transects (Fig 8).

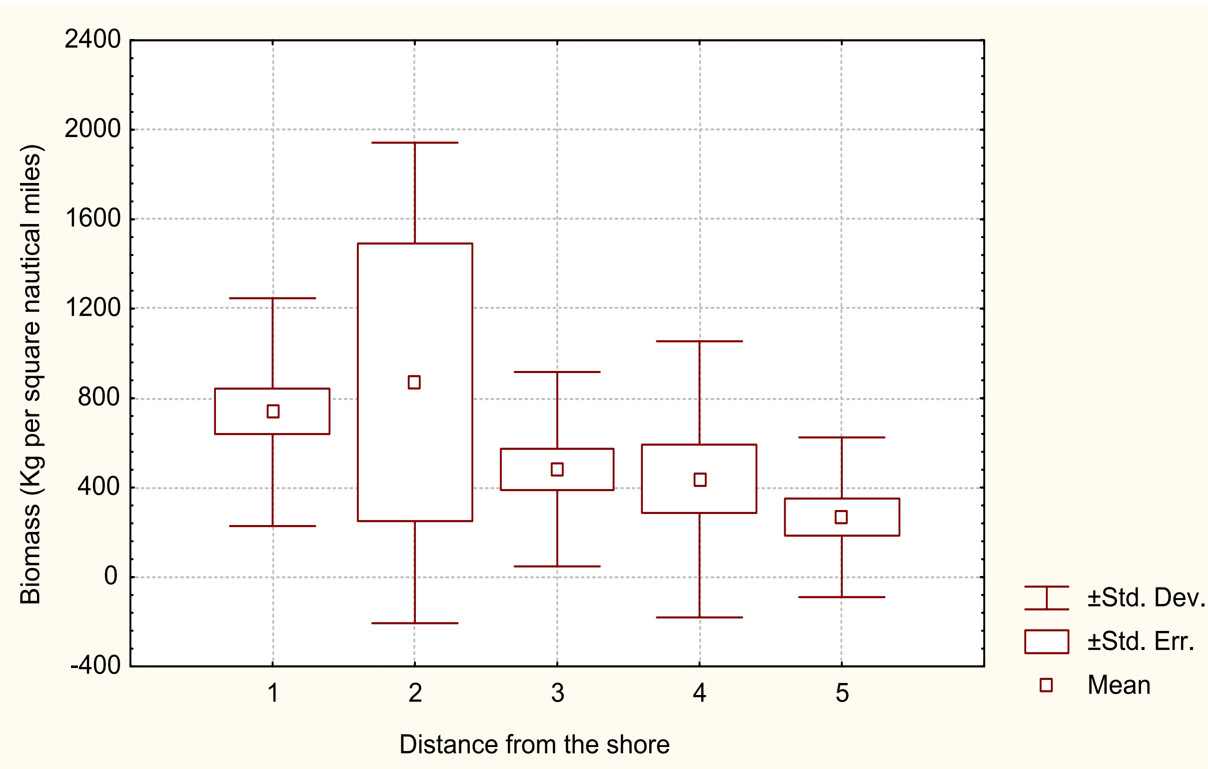


Figure 6. The spatial distribution of prawn biomass in the Malindi- Ungwana bay trawling grounds.

The biomass of prawns was distributed further offshore during April and May (Fig 8). In Malindi-Mambrui and Sandani-Kipini transects, high prawn biomass was observed offshore at 5 nautical miles in April and May 2002. Considerably high prawn biomass was estimated at Kalifi-Tana and Sedani-Kipini at the 5 nautical miles. In the other months, relatively lower prawn biomass were estimated at the 5 nautical mile transects compared to transects closer to the shore (Fig 8).

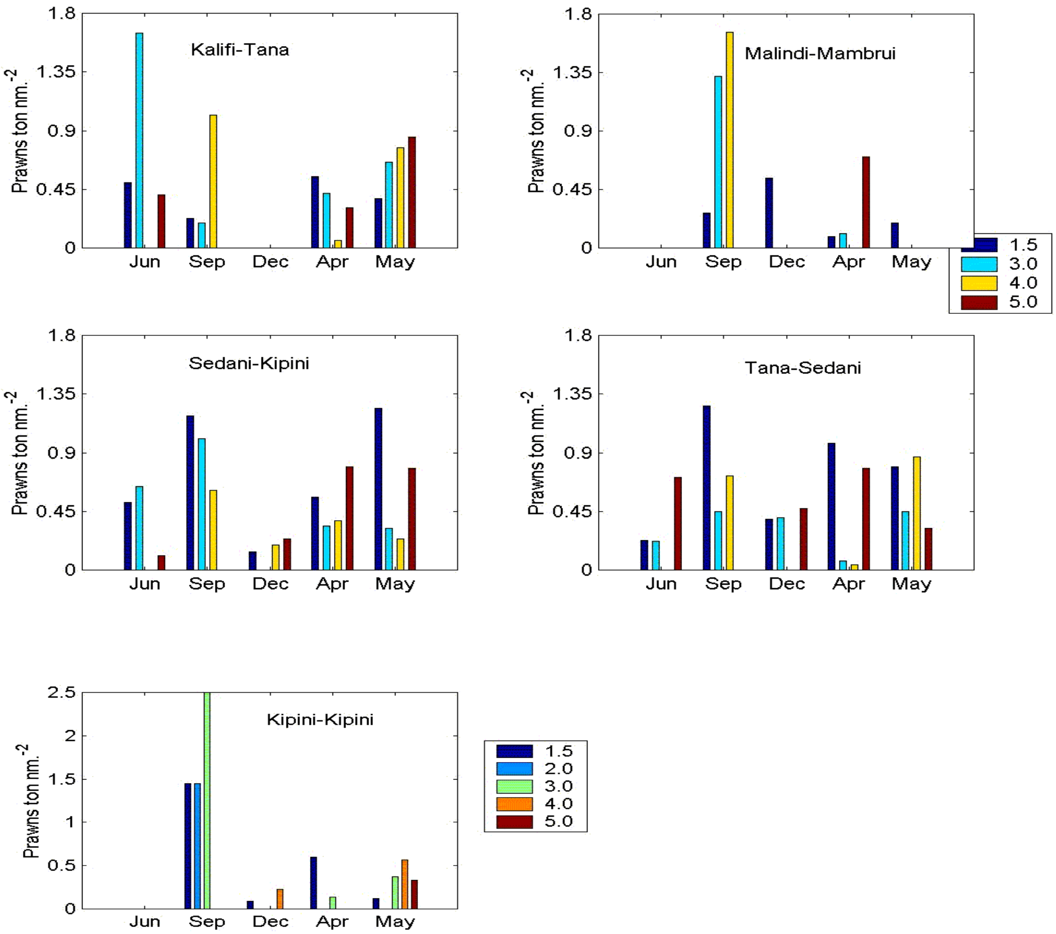


Figure 7. Temporal and spatial distribution of prawn biomass in the Malindi-Ungwana bay trawling grounds.

Catch per unit effort (CPUE) measured as kilogram whole mass of prawns per hour towed fluctuates between 20 to 95 Kg/hr (Fig.9). The estimated mean CPUE is 47 kilograms per hour.

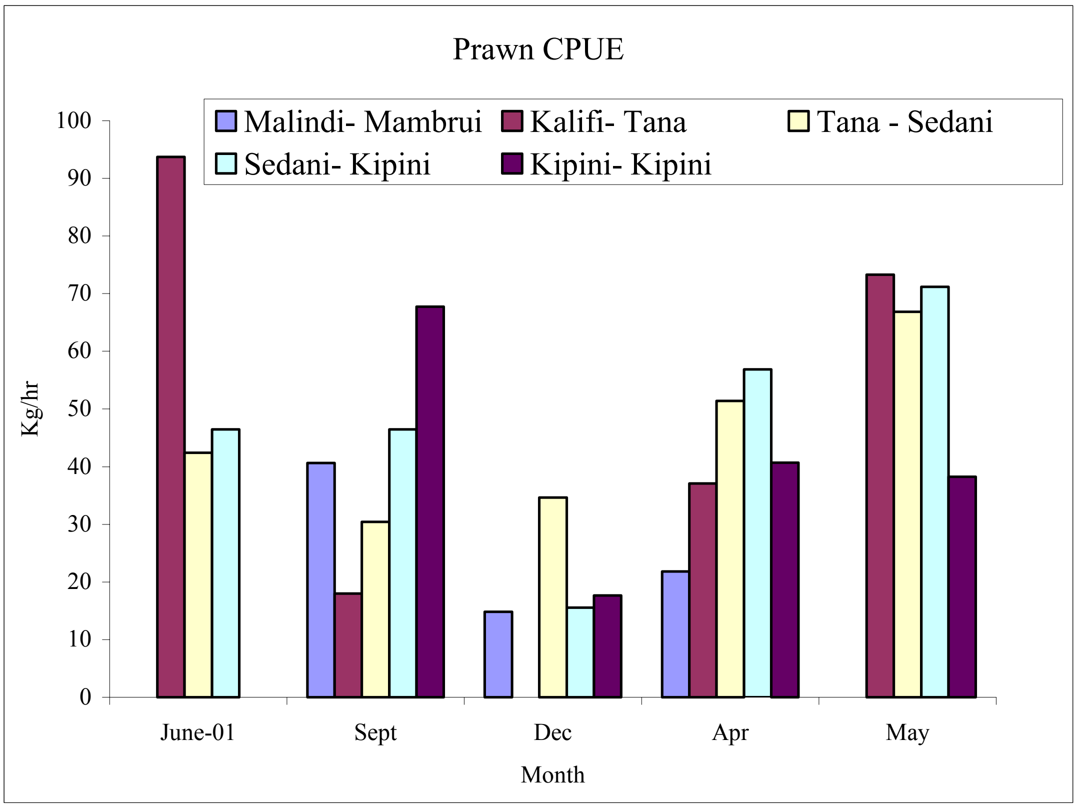


Figure 8. The catch rates of prawn by the trawlers in the Malindi- Ungwana area.

ESTIMATION OF MSY

Table 1 shows the production trend of prawns and the associated catch per unit effort. Total catches of shallow water prawns were high in 1998 and in 2001 (664 and 503mt respectively).

Table 1. Shrimp trawler data for Malindi- Ungwana bay (Source; Fishing companies)

Year	Number of trawlers	Shrimp catch (Mt)	CPUE (Mt/ trawler)
1996	5	307.4	61.5
1997	6	398.6	66.4
1998	6	664.7	110.8
1999	6	355.2	59.2
2000	4	373.5	93.2
2001	4	506.6	125.6

Using the surplus production model (Sparre and Venema 1992) and the data in Table I, the maximum sustainable yield (MSY) for prawns in the Malindi-Ungwana bay was estimated to be 433 mt/year. The maximum effort required to achieve the calculated yield is 4.7 trawlers.

FISH CATCH AND COMPOSITION

Target species

The target species for the semi-industrial trawling in Malindi-Ungwana bay is the shallow water prawns. The white prawn *Penaeus indicus* Milne Edwards, comprises 47% of the overall catch. *Peneaus monodon, Penaeus monocerous, penaeus semisulcatus* and *peneaus japonicum* contributes, 19.7, 12.34, and 1.3% respectively. However it was observed that spatial and temporal variability in the catch composition occurs.

Non Target Species

Retained bycatch

Table 2 shows the main fish species caught and retained by prawn trawlers. Retained fish species of commercial importance include Scienidae, Sphyraenidae, Scombridae, Pomatomidae. In the beginning of this exercise, prawn trawlers were not retaining the catfish. This has recently changed and the catfish caught are now being retained. All the listed species are discarded when landed in small sizes (<20cm).

Table 2: Showing main species of fish caught and retained by the prawn trawlers

Family	**Species**
Scienidae	*Johnius dussumieri* *Johnius amblycephalus*
Scienidae	*Otolithes rubber* (Malindi herring)
Sphyraenidae	*Sphyraena jello (Toa)*
Sillaginidae	*Sillago sihama*
Scomberomoridae	*Scomberomorous commersoni* *Scomberomorous maculatus*
Scombridae	*Rastrelliger hanargutta*
Mullidae	*Upeneus tragula* Upeneus Sulphureus
Pomatomidae	*Chorinemus tol*

Fish discards

The fish species, *Leiognathidae* ("Kolokolo") (3 species combined), *Pellona ditchella Trissocles setinostris*, *Trissocles malacabus,(*Sardines) *Tachysurus faliceps* (Cat fish) and *Trichiurus lepturus* (Ribbon fish, Mapanga) consists over 50% of the total discarded fish species. The temporal occurrence of these discards is shown in figure 10. No discernible trend is evident in their distribution.

Commercially important fish species occur in the discards and comprise on average 25% of the total fish discards. *Scienidae* (especially *Otolithes* rubber, Malindi herring and Johnius sp) and Pomadysis species (*Paramamba*) are the main fish discarded in this category. At larger sizes (>20cm) the same species are retained. No spatial distribution pattern was noted for these species.

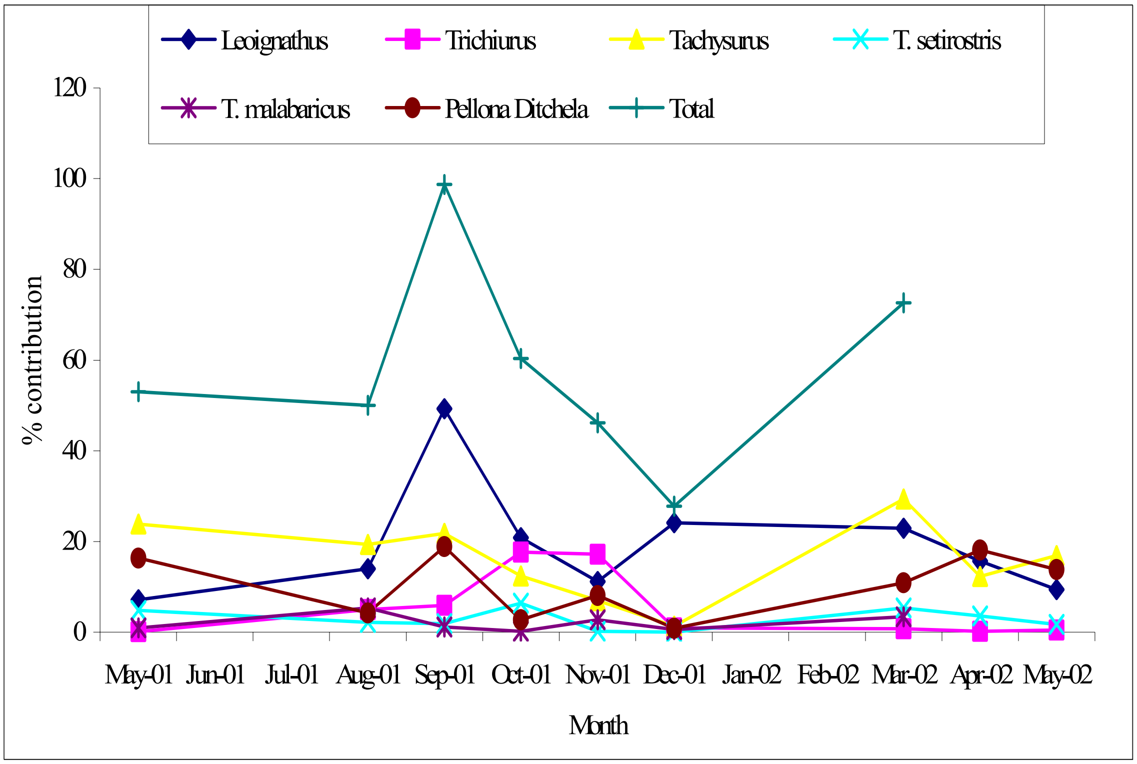


Figure 9. Temporal variation of commonly discarded fish species by the prawn trawlers in Malindi- Ungwana bay

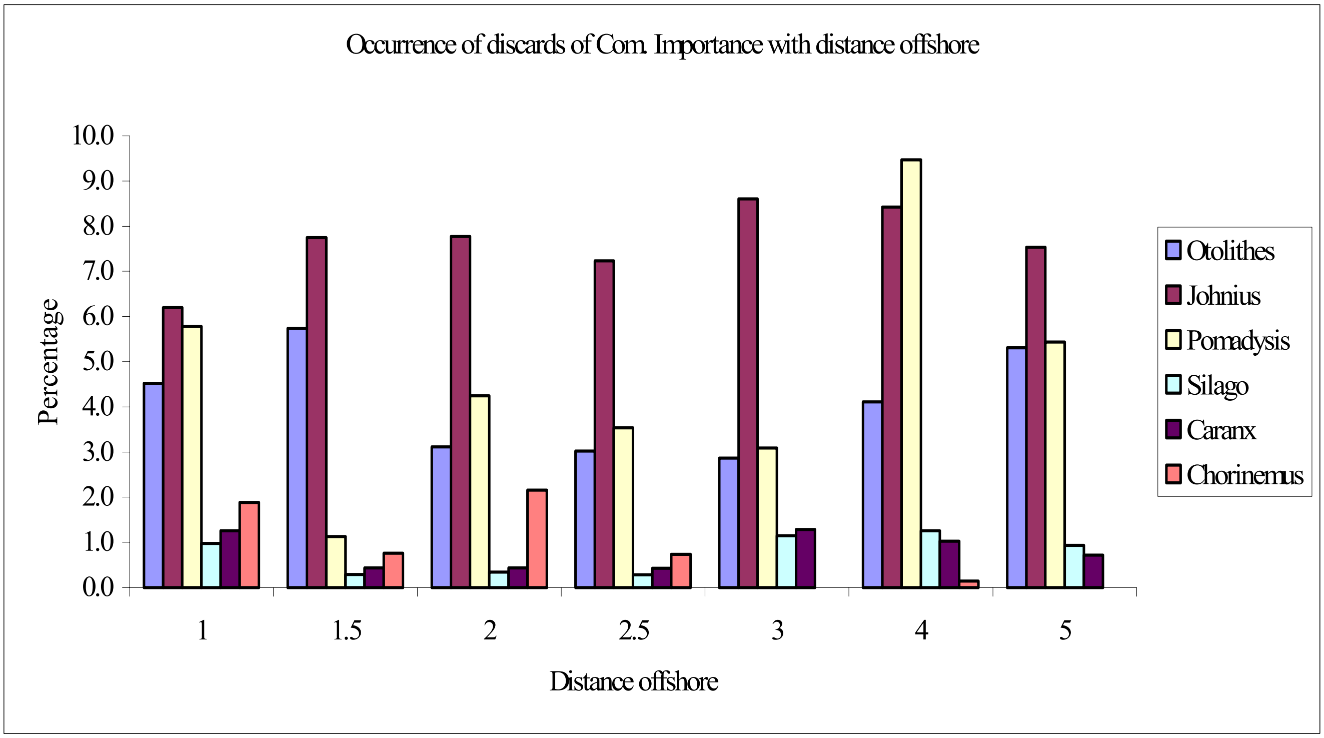


Figure 10. Temporal distribution commercially important fish species discarded by prawn trawlers in the Malindi- Ungwana bay area.

The Problem of Bycatch

The amount of fish retained fluctuated between 25 kilograms per hour in May 2001 to 450 kilograms per hour in October 2001. From the calculated CPUE's the average daily total catches are 472.1, 871, and 2743.6 Kilograms of prawns, retained bycatch and discards respectively. For every kilogram of prawns landed of 7.6 kilograms of bycatch and 5.8 kilograms of discards is produced. The seasonal dynamics of bycatch retention and discard is shown in Fig.12.

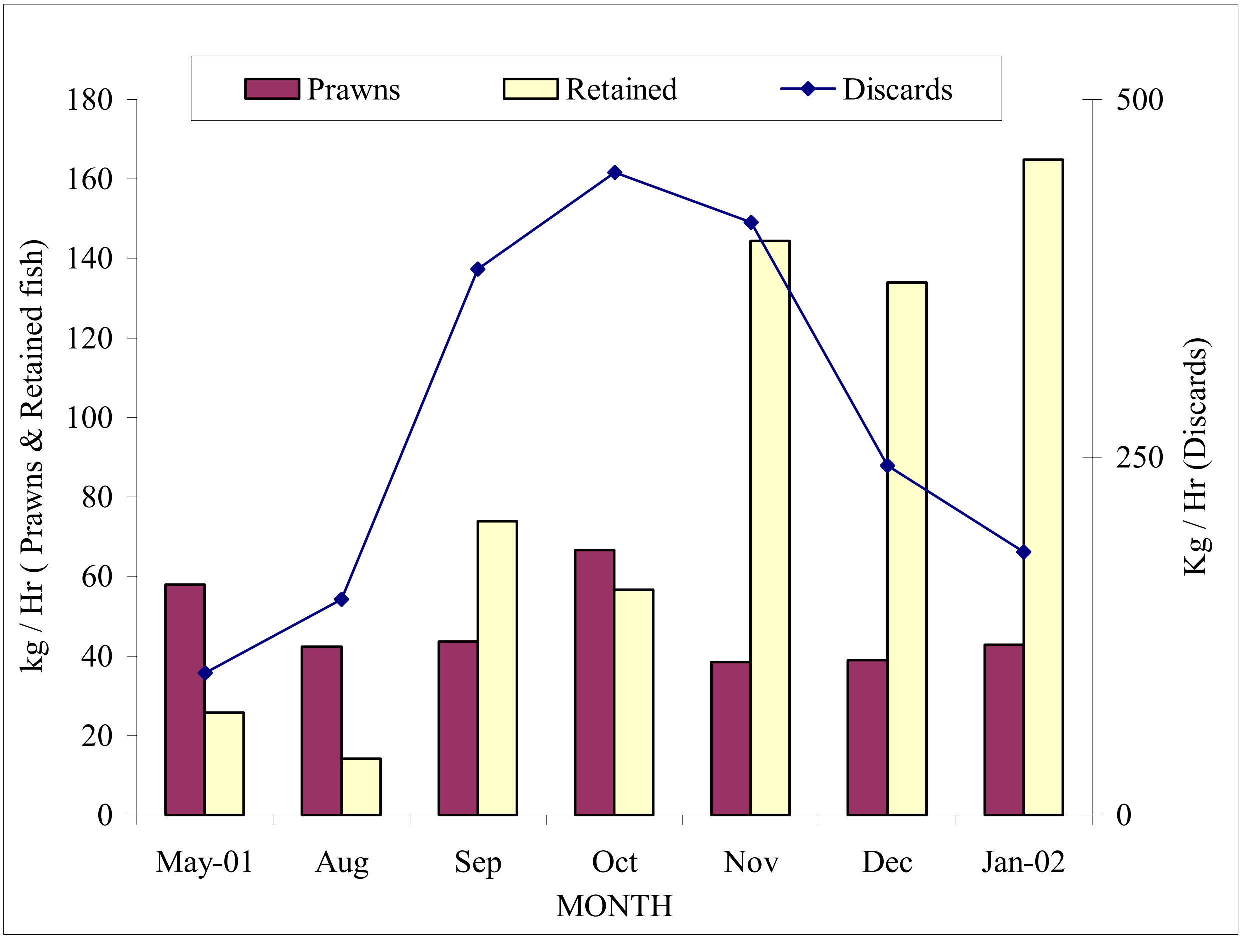


Figure 11. Monthly variations in catch effort for different fish categories of the prawn trawlers in Malindi - Ungwana bay.

TURTLE EXCLUDER DEVICE PERFORMANCE AND COMPLIANCE

To test the performance of the TED, a twin net beam trawler, with one net ringed with the TED and the other acting as a control were used.

ANOVA tests showed that there was no significant difference in catches between the two nets. However there was significant difference ($P<0.05$; $P=0.0005$) between the discards in the two nets. The net without TED caught more discard than the one fitted with a TED. Frequent clogging of nets by debril caused reduction prawn catch in some areas. Table 3 shows the turtle catches within the study area.

Table 3: Table showing incidental capture of turtles in the trawl net during the survey period

Month	Area caught	Depth (Meters)	Number	Species	Sex	Mortality	Comments
May-01	Ungwana bay		1	Green turtles			Released alive
Jun-01	Malindi-Mambrui	25	1	Hawksbill	Unsexed		Released alive
Jul-01			0				
Aug-01			Not sampled				
Sep-01			0				
Oct-01			0				
Nov-01	Malindi-Mambrui	15-28	2	Green turtles	Male and female		Released alive
Dec-01			0				
Jan-02	Malindi-Mambrui	18	2	Green turtles	Unsexed	1	One died
Feb-02	Malindi-Mambrui	15-25	10	Green turtles	Unsexed	1	One caught with a SA tag
Mar-02	Malindi-Mambrui	15-25	2	Green turtles	Unsexed		Released alive
Apr-02			0				
May-02			0				
Total			**18**			**2**	

CONCLUSIONS FROM THE STUDY

Fishery output has been on the decline (Ruwa et al 2001 and McClanahan 1997). A clear decline is reported adjacent to prawn trawling areas. Increased fishing effort, use of destructive fishing methods, and habitat degradation have contributed to the decline. Creation of the Malindi Marine Park has been blamed for reducing the fishing grounds.

Bycatch from the prawn trawling consists of high levels of juveniles of commercially important species, on average 25% of the total catch by weight. This in effect compromises the recruitment potential of the fishery. In addition to prawn trawling use of destructive beach seines (Ochiewo pers. Commun.) is continuing. Landing of juvenile fish by the artisanal fishermen is contributing to the threat facing the fishery and holistic mitigation measures are required to remedy the situation. The following measures were recommended:-

- Elimination of destructive fishing gears (beach seines etc)
- Elimination of fishing and landing of juvenile fish
- Demarcation fishing zones for the trawlers to protect the nursery grounds of fish

- Development of appropriate Bycatch Reducer Devices to reduce incidental capture of juvenile fish and reduce the quantity of bycatch.

THE ASSESSMENT OF THE IMPLICATIONSOF PRAWN TRAWLING ON THE FISHERY

Catch and Effort

From historical data, it is clear that the prawn catches have fluctuated with no discernible pattern. Unlike the finfish the prawn fishery shows no clear indication of decline. Prawns are R selected. They have high reproductive potential and are short lived. They are therefore capable of maintaining a relatively good stock despite being faced with the fishing effort witnessed through time. However, we recommend that the effort should be limited to sustainably exploit the prawn resource.

THE CURRENT PRAWN TRAWLING OPERATIONAL STRATEGIES

The results demonstrate that prawn trawlers prefer to fish within 1.5 nautical miles from the shore. This area is very critical for the recruitment of crustacean and fin fish juveniles (Mwaluma, this survey Mueni & Mwangi 2001). There must be a limitation on how close the trawlers can operate in order to have a refugia for both fish and crustaceans. A distance of 3 nautical miles from the shore was recommended from the study.

Prawns recruit into mangrove areas (which act as nursery areas) in larger members between October and March (Wakwabi 1988) probably for breeding. During this survey, mature prawns (all species) were encountered all year round. High abundance of mature prawns occurred in December, February and March. Trawling should therefore be closed completely during this period to safeguard the stocks. Catches for the deep water shrimps are significantly lower (27 kg/hr) compared to the shallow water shrimps (47kg/hr). Obviously, with the low catches and very limited deep sea fishing grounds (66 Nm^2) the high levels of prawn yields during the closed season is a clear indication illegal shallow water prawn trawling takes place during the closed season.

Distribution of Fishery Resources within Ungwana Bay.

Prawn biomass reduces with increased distance from the shore. Prawn biomass at 5 nautical miles offshore is statistically different from that at 1.5 nautical miles. There is no significant difference between catches in the other transects. The catch rate of discards at 1.5 nautical miles from the shore is almost the same as at 5 nautical miles offshore. The same is true for the catch of juveniles of commercially important species. This suggests that the whole bay is an important nursery ground for various fish species.

Between 6 and 14 nautical miles offshore the “RV Ujuzi, 1979-1981, estimated the prawns biomass at 0.3 tons/nm^2 (Iversen 1984). This survey has estimated the prawn biomass between the coast and 5 nautical to be in the range of 0.38 to 0.87 tons/nm^2 at 5 and 2 nautical miles from the shore respectively. The R.V Ujuzi estimated biomass at 5 nautical miles from the shore compares quite well with the estimates of the current survey. The mean prawn biomass for the area between the coast and 5 nautical miles not covered by RV “Ujuzi” offshore has been estimated to be 0.67 ton/nm^2. Results from offshore surveys between 10-100 fathoms carried out by “RV Ujuzi” (1979-81), “RV Fridtjof Nansen” (1975-76; 82-83), “RV Prof. Mesyatsev” (1976-77), “RV Manihine” (1965-66) showed the area to be mainly untrawlable (Venema 1984). These results show that shallow water prawns are concentrated more towards the shore.

The Prawn Fishery Maximum Sustainable Yield

The estimated MSY for the Malindi-Ungwana bay prawn fishery is 433 tons per year with a corresponding F_{msy} of 5.5 trawlers. However, we need to apply a precautionary approach when using the calculated MSY and F_{msy} for management due to the fact that monitoring of the prawn catches has been poor and the actual fishing effort has not undergone very substantial changes over the years. Detailed analysis needs to be undertaken to calculate very accurate yields for the fishery. The current fishing effort of 4 trawlers should therefore be maintained in line with the calculated F_{msy} of 5 trawlers. The size and number of gears should also be maintained so that we do not increase the effort indirectly.

The Problem of Bycatch in the Malindi-Ungwana Bay Fishery

The ratio of prawn to discard is 1:7 in the Malindi-Ungwana bay. This could have been higher had the prawn trawlers not started retaining more of the bycatch after the research program started. The average discard per trawler is 340 kilogram per hour, each trawler makes an average of four hauls, each lasting two hours. The total discard for the trawlers is therefore approximately 340kg/hr x 4 hauls x 4 trawlers bringing the total to 7tons/day. The bycatch comprises high quantities of small sized fish (Leiognathidae, clupidae), rays and sharks, juvenile of commercially important fish (Scieanidae) and turtles among others.

The fish species removed though not important for the artisanal fisheries have a very important ecological function in the ecosystem. Removal of huge quantities of bycatch can distort the food chain indirectly and make the fishery less productive. Efforts should be made to reduce the discards by appropriate bycatch Reducer Devices (BRD’s). In this survey, the TED significantly reduced the large animals caught e.g. Rays and sharks but did not reduce the small sized fish. BRD’s can reduce bycatch by between 30 and 40%$_o$ (Fennessy and Groeneveld 2001, Fennessy 2002, Robins – Troeger *et al* 1995 and Richard *et al*

1995). In the meantime, procedures and principals must be developed to retain and avail the bycatch to the local markets.

RECOMMENDATIONS FROM THE UNGWANA BAY RESEARCH

1. Trawling should be allowed in Ungwana Bay from 3 nautical miles offshore. “Relatively good prawn biomass” exist between 3 and 5 nautical miles from the shore. Restricting the trawlers to this area will protect the resources in the bay nearer the shore for prawns and fish breeding which has been demonstrated in this survey. It will also separate the area of operations of the artisanal and trawl fishery. Good monitoring by the relevant institutions must be put in place to compel the trawlers to adhere to these regulations. Modalities of fitting the VMS need to be explored to ensure trawlers can be effectively monitored.

2. The survey, clearly demonstrated that the destruction of artisanal fishing gears reduced significantly when trawling was restricted to day time and recommended that this should be made mandatory through legislation.

3. A closed season should be sanctioned from the beginning of November to the end of March to allow for prawn breeding and replenishment of the stocks. Breeding of most fin fishes also occurs during the same proposed closed season (Nzioka 1979, Mwatha 1997 & Kulmiye 1997) and also for lobsters (Kulmiye pers. Comm.). There is need to consider whether any other license should be issued during this period. However, no license should be issued to fish in the shallow water during this period.

4. Using a precautionary approach, a maximum of four prawn trawlers was recommended.

5. The industry should support the development and application of suitable Bycatch Reducer Devices (BRD’s). Retaining the fish bycatch must be fully addressed. Available opportunities of availing the bycatch to the local markets need to be fully considered.

6. Research and monitoring should continue with the full support from stakeholders.

7. Fishery legislation needs to be reviewed to address the proposed changes.

REFERENCES

Anon 2001. The annual fish statistics

Robins- Troeger J. B., Buckworth R. C., and Dredge M. C. L., 1995. Development of a trawl efficiency device (TED) for the Australian prawn fisheries. II. Field evaluation of the AusTED. Fisheries Research 22. 107- 117.

Wakwabi E. O., 1988. The population dynamics and fishery of penaeid prawns with special emphasis on *Peneaus monodon* Fabr. 1798, Msc. Thesis, University of Nairobi, Kenya, 235 pp.

Richard P. Mousey, Graham A. Baulch, Rick C. Buckworth 1995. Development of a trawl efficiency device (TED) for Australian prawn fisheries. 1. The AusTED design. Fisheries Research 22. 99-105.

Fennessy S. T., 2002. Preliminary investigations of a bycatch reducing device for the Tugela bank prawn trawl fishery in Kwa-Zulu Natal. South African Association for marine Biological Research. Unpublished report.

Fennessy S. T., and Groeneveld J. C., 1997. A review of the offshore trawl fishery for the crustaceans on the east cost of South Africa. Fisheries management and ecology, 4, 135- 147.

Ruwa R. K., Mukira M., and Mwatha G., 2001. Fisheries profile of the Diani- Chale, Kwale District. Report to the IUCN Eastern Africa regional office. 41 pp.

Nzioka R. M., 1979. Observations on the spawning seasons of East African reef fishes. Journal of Fish Biology. 14: 329-342.

McClanahan, T. R., 1994. Kenya coral reef lagoon fish: Effects of fishing, substrate complexity and sea urchins. Coral Reefs 13: 231- 241.

Venema S. C., 1984. Review of marine resource surveys in Kenyan waters. The proceedings of the NORAD- Kenya Seminar to review the marine fish stocks in Kenya. Mombasa, 13-15. 61- 62.

Brouchmann B. S., 1984. Fisheries development and economy. The proceedings of the NORAD- Kenya Seminar to review the marine fish stocks in Kenya. Mombasa, 13-15. 135- 140.

Matagyera W. B., 1984. Distribution of some deepwater prawns and lobster species in Kenya waters. The proceedings of the NORAD-

Kenya Seminar to review the marine fish stocks in Kenya. Mombasa, 13-15.

Iversen. S. C., 1984. Kenya marine fish resources in waters deeper the 10 m.investigated by R/V " DR. Fridtjof Nansen". The proceedings of the NORAD- Kenya Seminar to review the marine fish stocks in Kenya.Mombasa, 13-15. 33-60.

Mueni, E., and Mwangi J., 2001. A survey on the use of turtle excluder device (TED) in trawlers along the Kenyan coast. KWS Technical Series. 11pp.

Wamukoya, G. M., Salm R. V, (Eds.) 1997. Proceedings of the western Indian Ocean Turtle excluder device (TED) training workshop, Mombasa, Kenya, IUCN Technical report. 14- 15.

Gove D., Pacule H., Goncalves M., 2001. The impact of Sofala bank (Central Mozambique) shallow water shrimp fisheries on marine turtles and the effects of introducing TED (Turtle Excluder Device) on shrimp fishery. WWF report. 16 pp.

Mwatha G. K, 1997. The reproductive biology and fishery of the blue marbled parrot fish, *Leptoscarus vagiensis* in the inshore waters of Kenya. Msc. Thesis, University of Nairobi. 97 pp.

Sparre P. and Venema S.C., 1998. Introduction to tropical fish stock assessment. FAO fisheries Technical paper 306/1 Rev2

Kulmiye A. J. 1997. The reproductive biology of the thumbprint emperor, Lethrinus harak (Forsskal 1775) from the marine waters of Kenya with special emphasis of its fecundity estimates

Witte F. and van Dansen W. L. T., (Eds.) 1995. Fish stocks and fisheries of lake Victoria. A handbook for field observations. Cardigan, Great Britain: Samara Publishing. 404 pp.

CHAPTER 3:ASSESSMENT OF NATURAL AND ANTHROPOGENIC IMPACTS IN MALINDI-UNGWANA BAY

THE BENTHIC COMMUNITY OF THE MALINDI-UNGWANA BAY

Esther

INTRODUCTION

Marine bottom-dwelling organisms provide a number of extremely important ecosystem services. The benthic food web is an important element in nutrient regeneration in the benthic system. It differs essentially from its pelagic counterpart since it represents the slower part of the nutrient cycle, due to longer transport paths. With its strong chemical and biological gradients, the benthic system has a vertical structure that enables its different layers to interact hence giving many types of microenvironments. The deposit feeding macrobenthos is a major link between the benthic food web and higher trophic levels in the system. The benthic organisms also form food for fish. Thus the benthic community forms an important part of the benthic ecosystem. Biogeochemical flows are altered when trawling and dredging equipment churns up bottom sediment and resuspends it in the water column. During the trawling activities, the sock-like net is pulled along the seabed, and this net is kept on the bottom by means of a weighted foot line. The weights and pulling of the net is said to affect the benthic community.

Infauna play a significant role in the sedimentary processes. Through the production of mucus or through specific structures on the sea floor, they help prevent sediment disturbances. Mucus can act as glue causing sediment particles to stick together so that higher velocity currents are needed to erode the sediments. Macrofaunal animals also modify sediments in the benthic boundary layer with profound implications for both physical and chemical processes through Bioturbation (biologically mediated sediment-water interactions).

RESEARCH METHODS

Samples of organisms were collected within the Malindi- Ungwana Bay and presented in 5 major locations: Malindi, Kalifi, Tana, Sadani and Kipini. Samples of discarded material from Trawlers were collected in the months of December (2001), April (2002) for strategic (cruise) samples and monitoring samples were collected in the months of October, November (2001), January and March (2002). The different benthic organisms were sorted out and identified. These organisms represented the epibenthic organisms i.e. the organisms found on the surface of the sediment.

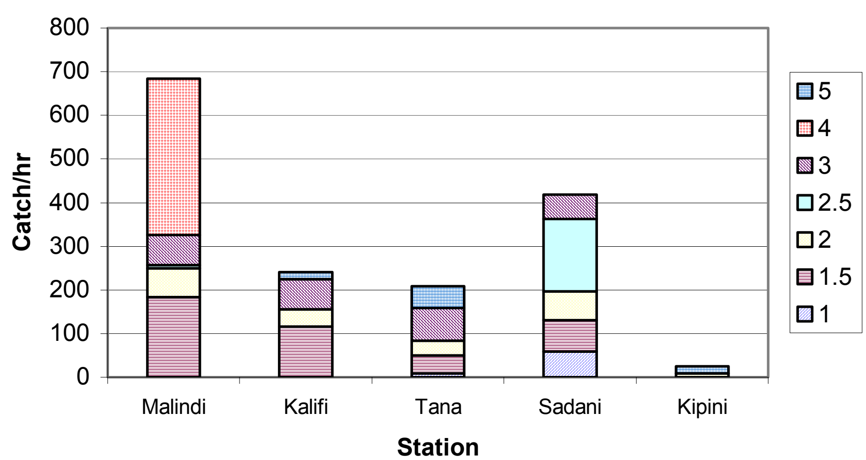
Sediment for infauna analyses was collected using a grab. Strategic sampling was done in December (2001), April and May (2002) and monitoring sampling was done in October and November (2001) and in January and March (2002). The sediment collected was placed in a 1 mm meshed size sieve and sieved using seawater. The sediment remaining in the sieve was placed in jars and preserved and then transferred to the lab for analysis.

RESULTS AND OBSERVATIONS

Epibenthic Organisms

A total of 72 epibenthic species were recorded, which include 26 flora and 46 fauna. Red algae dominated for flora while Crustacea dominated for fauna. The epibenthic organisms encountered included crabs, tiny shrimps, mantis shrimps, sponges, molluscs, seaweeds/seagrasses, starfish, jellyfish/comb jellies sand dollars, flatworms, sea pens and other types of crustaceans. Fig.1 shows the mean biomass/hour for each station for the different distances off-shore. The highest biomass was recorded in December at Malindi 1.5 nm. This was attributed to mantis shrimps. The lowest biomass was recorded in April at Kipini 2nm. Generally for all areas, the highest biomasses were recorded during the cruise periods compared to the monitoring periods (apart from Kalifi in October). This could be due to the larger area covered during this sampling to cover upto 5nm, where the trawlers would otherwise not trawl. Mantis shrimps (47%), crabs (29%), molluscs (4%) and seaweeds (11%) contributed higher percentage compositions by weight in most areas.

Fig.2: Mean biomass/hr in the different stations



Infauna

The highest densities of infauna were recorded in Malindi from October to January and from April to May the highest densities were recorded in Kipini, indicating seasonality in the infauna distribution. In May was the highest density. Kipini 4nm and the lowest was in December at Tana 3nm. The biomass was highest in December. The highest biomass was recorded in January at Malindi 0.6nm and was attributed to Bivalves. Overall, the highest density was recorded in Kipini (4nm) as shown in Fig.6 and the highest biomass was recorded in Kalifi (2.5) as shown in Fig.7. A total of 53 infauna taxa were recorded with polychaetes dominating with 30 taxa. The species diversity (H') varied from 0.88 in Kipini to 1.24 in Sadani. Sadani had the highest diversity index.

Fig.6: Infauna densities in the different stations

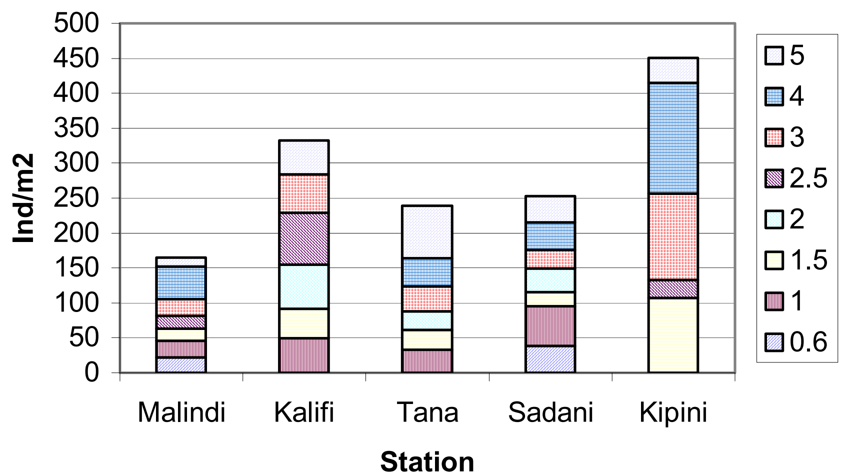
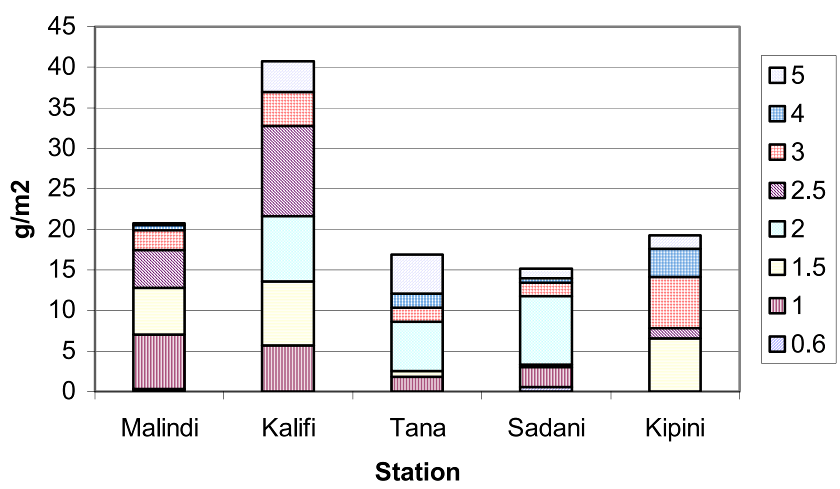


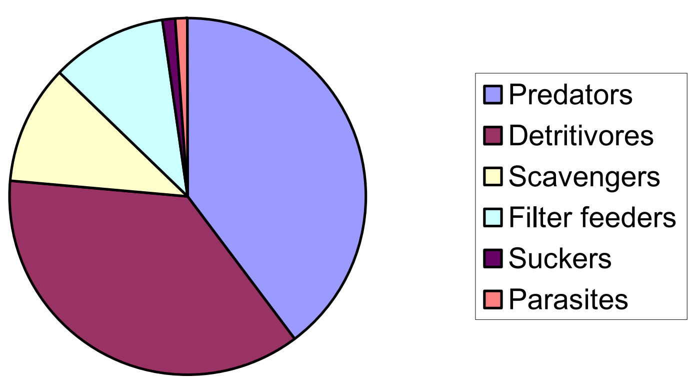
Fig.7: Infauna biomass in the different Stations



THE BENTHIC COMMUNITY

The benthic community of the Bay was composed of various feeding groups which include predators (carnivorous), detritivores, scavengers, filter feeders, suckers and parasites. Figure 8 shows the percentage compositions of the these groups. Predators (39%) and detritivores (34%) had the highest percentages.

Fig. 8: Percentage composition of feeding groups in Malindi-Ungwana Bay



DISCUSSION

The Ungwana bay benthic community has been disturbed and this is indicated by the dominance of predators, detritus feeders and scavengers. This is supported by studies on the long-term changes in the Northern Adriatic Sea benthos in a trawled area by Kollomann & Stachowitsch (2001), showed how the benthic community of suspension and filter feeders shifted to one dominated by detritus feeders. Therefore one of the effects of trawling is change in the benthic community structure. In addition, an EU (European Union) funded research has shown that commercial beam trawling has detrimental effects on the structure and composition of benthic communities in the North Sea (Keegan *et al*., 1998). It appeared that short –lived species were favoured while longer-lived species are more adversely affected with the result that the disturbed communities may favour scavengers, and predators other than fishery target species.

THE EFFECTS OF TRAWLING ON THE BENTHIC COMMUNITY

Different fishing methodologies vary in the degree to which they affect the seabed and the benthic community. Benthic communities experience continual natural disturbances at various scales in time and space. In general, shallow continental-shelf sea environments experience more frequent disturbances than deeper sea environments that are not exposed to wave action and strong currents. Studies have revealed intertidal dredging as having the most negative impact, beam trawling having less negative impacts and otter trawling having the least negative impacts (Kaiser,et al., 2002). Many marine organisms dig into muddy bottoms to create burrows and tubes to hide from predators and capture food. On these bottoms, trawl gear collapses the burrows and breaks the tubes, exposing inhabitants to predators. Some of these small species -- essential links in the marine food chain – are unable to rebuild their homes. This disturbance and displacement by trawling can however create “new” habitats which can be easily colonized by opportunistic organisms.

Consequences

Trawling eventually reduces species diversity and abundance. This is the present situation in the Ungwana bay, exhibited by the low species diversity and low abundance. Trawling reshuffles bottom-dwelling communities at many levels. For instance, increased murkiness of the water column may cause a shift from species that hunt by sight to those that locate prey by sound or touch, or from filter-feeders to deposit-feeders. In Ungwana bay, predators and deposit feeders dominate with lack of suspension or filter feeders. This situation is found in disturbed areas and the community structure of this area has changed with a reduced structural complexity. In terms of biomass, bivalves and brittle stars dominate in Ungwana bay. These are organisms that are flat structured and covered by hard shell, which indicates a dominance by organisms much adapted to disturbance.

Often in trawled areas, short-lived, rapidly-reproducing creatures (such as nematode worms) move in, tending to replace larger, longer-lived organisms (such as sponges or shellfish) that take longer to propagate and re-establish themselves. This is the situation found in Ungwana bay where short-lived organisms such as polychaetes and nematodes dominate. Typically, reducing structural complexity results in an increased abundance of opportunistic, more adaptable species that benefit from disturbance, at the expense of a richer variety of species and more fragile organisms. Although information on the benthic community in Ungwana bay before Trawling commenced is lacking, the present community recorded is similar the ones common in disturbed areas.

REFERENCES

Kaiser, M. J.; J. S. Collie; J. H. Stephen; S. Jennings & I. R. Poiner. 2002. Modification of marine habitats by trawling activities: prognosis and solutions. Fish and Fisheries 3: 114-136.

Keegan, B. F dir; B. van Marlen; M. J. N. Bergman; W. Zevenboom; R. Foteyne; K. Lange & J. Browne. 1998. Reduction of adverse environmental impact of demersal trawls. Third European Marine Science and Technology Conference (MAST Conference), Lisbon 23-27 May 1998. Project Synopses Vol. 6: 313-314.

Kollomann, H. & M. Stachowitsch. 2001. Long-term changes in the benthos of the Northern Adriatic Sea: A Phototransect approach. Marine Ecology 22(1-2): 135-154.

ASSESSMENT OF SOCIO-ECONOMIC IMPACTS OF PRAWN TRAWLING ON THE ARTISANAL FISHERIES OF MALINDI AND UNGWANA BAY

Jacob Ochiewo

INTRODUCTION

Artisanal fishing is a major source of livelihood to about 6,000 fishermen along the Kenyan coast. Each of these fishermen supports another 6-10 dependants. Fish has a lot of importance in the diet of coastal communities and is the cheapest source of animal protein available to many coastal households. So far artisanal fisheries produce approximately 97% of the total annual marine fish landings and only 3% is landed by the commercial prawn trawlers. In the Malindi-Ungwana Bay area, artisanal fishermen are limited by their simple canoes and fishing gears to the shallow inshore waters. Catch by the prawn trawlers fishing in the common ground normally consists of 70-80% bycatch. Further statements on Fisheries is given by Mwatha et.al in the other paper in this document. Competition for the same fishing ground and the high level of bycatch has caused resource use conflicts between the prawn trawlers and artisanal fishers, especially gill-netters. We set out to assess the conflicts with the following objectives.

OBJECTIVES OF THE STUDY

- *To assess user conflicts between prawn trawlers, artisanal fishers and other stakeholders*
- *To assess the socio-cultural and economic characteristic of the local fishers.*
- *To determine the resource use patterns in the Malindi and Ungwana bays*
- *To undertake a cost-benefit analysis of prawn trawling*

BACKGROUND OF THE STUDY AREAS

Kipini, which is the northern most study site, is strategically located in the Tana delta and is a typical ancient settlement with a long history of artisanal fishing activities. The adjacent sea is recognized as a rich fishing ground. Prawn trawling is carried out in the waters adjacent to Kipini and the mouth of Tana river. As a result, local fishermen seasonally share fishing grounds with the prawn trawlers resulting into conflicts.

Ngomeni is a typical fishing settlement located a few kilometres north of the Sabaki estuary. From oral tradition, Ngomeni was a small village with only 5-10 households at independence in 1963. Today, the village has over 400 households and a total population of about 2,800 persons heavily dependant on fishing. The number of small-scale fishermen fishing within the shallow inshore waters using small canoes with small gillnets, handlines and seine nets is over 200. The others are semi-industrial fishermen who use big gillnets and long lines.

Malindi, the southern most study site, is an urban set up with diverse economic activities. Its monetary economy is dominated by tourism and commerce that overshadows all other activities. However, artisanal fishing still plays a very important role in providing livelihood to over 1000 households. The trickle-down effects of fishing are felt in almost all the corners of Malindi. Prawn trawling activities occur in the adjacent waters resulting in conflicts with the artisanal and semi-industrial fishers.

RESEARCH METHODS

Socio-economic assessments were conducted in all the three study sites to learn about the social, cultural, political and economic conditions of the fishing households, and to assess the conflicts in the Malindi - Ungwana Bay fishery. Prior to field data collection a reconnaissance survey was conducted to finalise the selection of study sites, collect preliminary information on the location, the number of stakeholders and identify logistical requirements based on local conditions before the actual field data collection. During the reconnaissance survey, a semi-structured interview guide was tested. The respondents interviewed included, fishermen, fish dealers, and leaders from the fishermen's cooperative societies in Malindi, Ngomeni and Kipini. Socio-economic assessments were conducted using semi-structured interviews, focused group discussions, key informant interviews and observations. Semi-structured interviews were applied at the beaches, fish "bandas" and a few at the household level

The respondents represented their respective households since most of them were actually the household heads. Sixty respondents were interviewed from each site. Random sampling was used to select interviewees. Focus group discussions were held with groups that were formed on the basis of occupation, scale of operation and membership to societies and associations. The focal groups included groups of fishermen, medium scale fish dealers, small-scale fishmongers, and fishermen cooperative society leaders. Continuous observation was used to gauge the sequence of fishing activities, crafts and gears used, and other activities related to fishing.

RESULTS OF THE STUDY

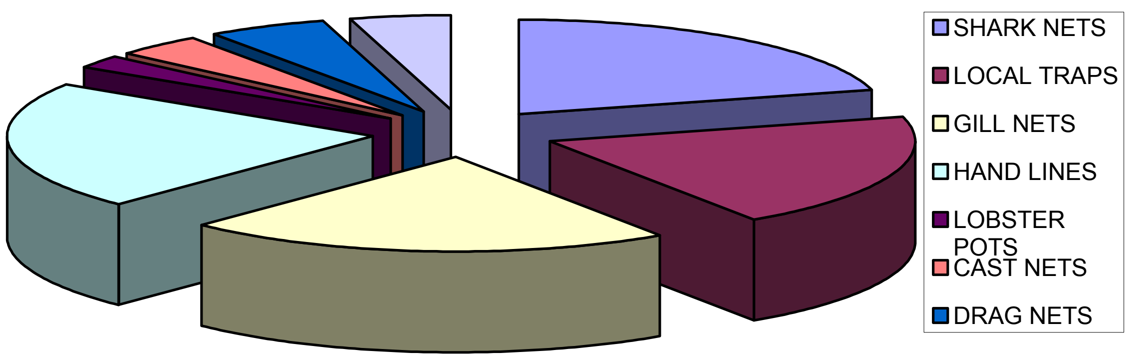
The study noted that the greatest conflict occurred between local fishermen who use gillnets and the commercial prawn trawlers who share common fishing grounds. Three causes of conflicts were identified; declining artisanal fish catches and loss of income, destruction of gillnets by prawn trawlers and excessive bycatch and discards from prawn trawlers. Depletion of preferred species, and incidental catches of threatened species was also cited as an issue of concern.

DECLINING ARTISANAL FISH CATCHES

Interviews indicated that significant fish decline started around 1985. Towards 1988, the decline became critical. This was attributed to trawling activities, destructive fishing methods used by some artisanal fishermen, and increased number of fishermen, gears and fishing vessels especially canoes and outrigger boats. Apart from bottom trawling, some of the notable destructive fishing methods include the use of small-mesh size nets, beach seines (Fig. 3) and traditional plant poison especially *euphorbia* spp, which is known locally as "*mkanga*".

In the beaches of Malindi and Ngomeni, it was observed that many fishermen

Figure 2: Distribution of fishing gears in Malindi District 2001/2002



were using beach seines. Many fishermen confirmed use of small mesh-size nets but emphasised that they target particular species that are small in size such as "*simbe*". It was evident from the fish catches that many artisanal fishermen caught a lot of under-size fish.

At Ngomeni, a group of fishermen have agreed to work with the Fisheries Department to fight against the use of beach seines and promote environmentally friendly fishing practices.
From the matrix response it is evident that prawn trawling is perceived to be the leading cause of decline in the artisanal fish catches in all three sites. This is attributed to the associated excessive bycatch and discards that result in juvenile wastage. It is followed by the use of destructive fishing gears.

Excessive bycatch and discards

The bycatch, which is discarded, comprises fish that are highly valued by the artisanal fishing households. This includes Malindi herring ("gufadi"), catfish, wolfherring and ribbonfish ("panga"), sardines ("simu"), rays ("taa"), crabs ("kaa") especially the blue swimming crabs and the edible mud crab Scylla serrata, juvenile prawns ("kamba") and juvenile squids ("ngisi"). Of these species, the Malindi herring and sawfish are reported to be facing depletion. Other species whose catches show declining trends include scavengers; rabbit fish; Barracuda and roc cod. However, these species are caught from different fishing grounds and their depletion could not be attributed directly to trawling.

CHANGES IN CONSUMPTION HABITS

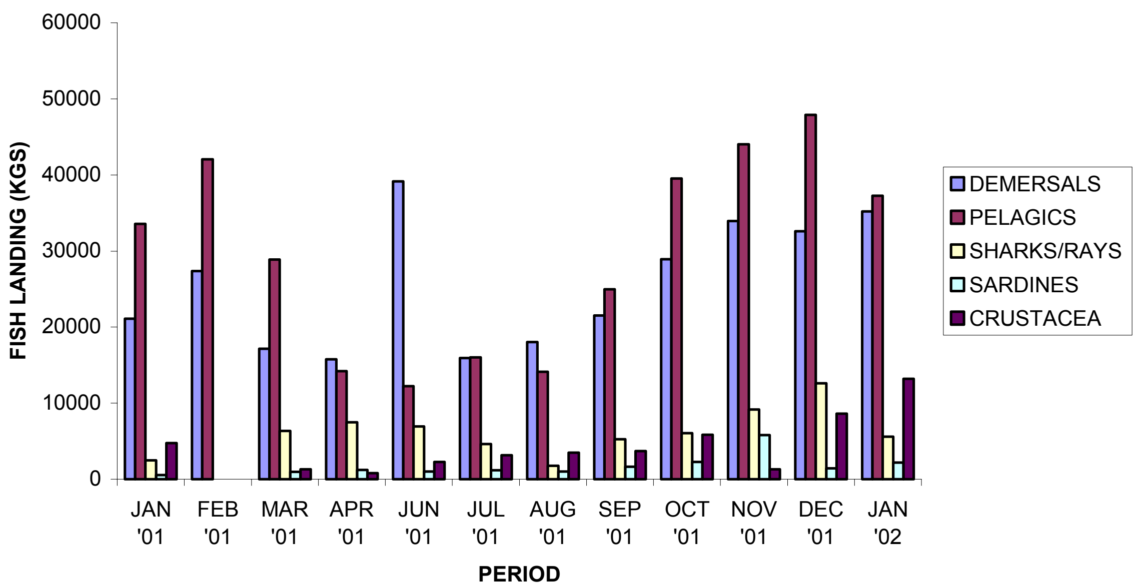
As fish gets increasingly scarce some low value species such as wolf herring, ribbonfish, sardines and rays now command a high demand in the market. To express their anger the local fishermen have compared the discards to a collection of seagrasses that are deposited at the beaches of Malindi. The discards are being perceived to reflect juvenile wastage that threatens sustainability of fish stocks. Photograph 1 below shows a consumer buying wolf herrings and ribbonfish ("panga") from fishermen at a fish-landing beach at Ngomeni. "Panga" is now a household delicacy while in the past it was being thrown away. Today, one kilogramme of "panga" sells at between Kshs. 25-30. Photo 2 shows a fisherman haggling with buyers (not in the picture) over the price of a ray ("taa") at Ngomeni.

CAUSES OF FISH DECLINE

While the prawn trawlers contribute most significantly to excessive bycatch and discards, it was noted that some activities of the artisanal fishermen also contribute to the same. Many artisanal fishermen use small-mesh size nets thereby landing a lot of juvenile fish and other organisms, which are not the target of the fishery. Similarly there are accidental catches of some threatened and/or endangered species such as sea turtles (Loggerhead, hawksbill and green turtles. From the interviews, it was evident that no fisherman ever leaves a sea turtle if it is entangled by a gillnet. Fishermen often slaughter them and only carry the meat to the beach. Sea turtles are in high demand because of the high medicinal value of their oil, which is believed to be a cure for asthma and other diseases, and its meat, which is used by elderly men to boost their reproductive capacity especially when they marry a younger wife at old age.

Photo 1: A consumer buying wolf herrings and ribbonfish (“panga”) from a fish landing beach at Ngomeni.

Figure 1: FISH LANDINGS IN MALINDI DISTRICT (JANUARY 2001 - JANUARY 2002)



RESULTS

Fishermen started recognizing decline in per capita catch around 1985, this became more severe around 1988. The trends in fish catches between January 2001 and January 2002 in Malindi district is shown in Figure 1. Similarly, figure 2 shows catch trends in Kipini during the same period.

From figure 1 above, it is evident that in the Malindi Bay, catches were very low between April and September but were high between October and March during the last two years. This confirms the assertion about the dependence of fish catches on the two main seasons in the Kenya coast.

Figure 2 below explains seasonality variations in Kipini. It is evident that Kipini experiences almost a similar trend as Malindi district. Fish catches were generally low between March and September during the two years and were high between October and February. In 2002, very low catches were recorded in Kipini in the month of February unlike the usual trend. (see also Mwatha et.al. in another paper, in this document).

Depletion of some preferred fish species especially sawfish ("Papa Upanga") has raised a lot of concern from the artisanal fishers. Saw fish is highly valued by the local fishermen due to its high economic value but is has become very scarce

ANALYSIS OF FISHERIES POLICY AND GOVERNANCE

Existing weaknesses in fisheries policy and institutional constraints can limit enforcement and contribute to the emergence of conflicts.

Assessment of Weaknesses in the fisheries policy and institutional constraints

The current fisheries policy defines what constitute offences and their associated penalties. The Fisheries Act was reviewed in this respect. The penalties that are in the form of fines are practically too low to deter offences. For example, a fine of Ksh.6,000 cannot deter any fisherman who operates a large vessel with good fishing equipment from venturing into the no go zones. The policy also emphasises that trawlers should operate beyond 5 nautical miles from the shoreline. However, the prawn trawlers in Kenya target only the shallow water prawns that are available mainly between 1.5 - 5 nautical miles. The trawlers have been operating illegally in this area for a long time. From this reality, this provision is not enforceable if the resource is to be exploited for commercial gains. The artisanal fishermen on the other hand are aware of the existence of this policy and therefore cast all the blame on the Fisheries Department for non-enforcement of this policy.

On institutional constraints, the Fisheries Department currently lacks monitoring capability since it does not have an efficient surveillance vessel that can operate in the Ungwana bay nor does it have financial resources that can effectively support a vessel monitoring system. The current budgetary allocation to the department is too limited and the available technical personnel are also too few. There are attempts to bring on board the Kenya Navy but the budgetary implications are too heavy.

Destruction of gillnets before and during the Study

In the past when trawling was done at night, there were frequent incidences of gillnet (jerife) destruction by prawn trawlers. Gill-netters and prawn trawlers often operate on the same fishing grounds. However, from May 2001, the trawlers were issued with research licences that restricted them to day trawling. Only two incidences of accidental destruction of the nets was reported. The reduction in the number of incidences suggests that time is an important variable in the determination of mitigating measure.

In cases where gillnets have been destroyed by trawlers, long bureaucratic procedures, delays in compensation by trawlers impacts negatively on artisanal fishermen. The bureaucratic procedures are interpreted by the fishermen as collusion between the responsible Government Department and the trawler owners.

CONFLICTING INTERESTS BETWEEN SOME ARTISANAL FISHERS AND FISHERIES DEPARTMENT

As managers the Fisheries Department requires all artisanal fishermen to register their fishing gears and crafts. However, not all fishermen comply with the registration requirement. When gears that are not registered are destroyed, it is normally difficult for the Fisheries Department to register a claim and recommend compensation. The Fisheries Department has also banned the use of beach seines, small–mesh size nets/monofilaments as well as the use of poison. Some fishermen feel that these are the most efficient techniques and therefore prefer to earn a better living today at the expense of the future. They are however fully aware that these techniques are destructive and argue that the Fisheries Department should provide them with better alternatives instead of simply confiscating the gears. It is clear from figure 2 that shark nets, gillnets, hand lines/long lines and local traps are the most widely used fishing gears in the Malindi bay. This also applies to the rest of Ungwana bay. Anything affecting the use of any of these gears is likely to raise conflicts in the fishery.

ASSESSMENT OF THE ROLE OF MARKET FORCES IN THE CONFLICT

With a rapid population growth rate of 3.1%, which exceeds the national growth rate of 2.9%, the coast has a much bigger market potential for fish than is currently experienced. At the national level demand for fish is increasing. Fish and other marine products are exported to the European Union and Asia. In addition, the big tourism industry provides an important market for both fish and other marine products. Currently, there is increasing commercialisation of juvenile fish in the domestic market characterized by declining real fish prices. This poses a threat to sustainability by increasing fishing effort and the use of destructive fishing technology.

Perfectly functioning markets are efficient mechanisms for allocating scarce resources among competing uses over time. Some markets however, do not function well. The inefficient use of bycatch in the Malindi-Ungwana Bays is a manifestation of the malfunctioning and distortion of the fish and fish product market, and the assumed lack of market for some fish species. The prices generated by the market for retained bycatch do not reflect the true social costs and benefits. Both the suppliers and consumers do not have sufficient knowledge about the market. Malfunctioning fish market explains why some bycatch is assumed to be of low value and therefore 'should' lack market. Such bycatch species are discarded while there is sufficient demand. Examples of species that are discarded but command market price include the catfish, sardines, wolf herring and ribbonfish, crabs, and rays (see Mwatha et.al ibd). Consumers have revealed their preferences for some of these species compared to others and it is evident that they are willing to offer to purchase different species of some of the discarded species.

Today approximately 400 fishmongers buy bycatch from one trawler company in Mombasa city everyday, while initially very little bycatch was being retained for the market. Currently attempts are being made to retain as much bycatch as possible. The trawler company is targeting the Mombasa market and has left the Malindi market to the local artisanal and semi-industrial fishermen.

Impacts caused by lack of adequate fish storage

Constraints in the distribution and marketing of fish also interfere with the efficient functioning of the fish market. In the Malindi Bay and Ungwana Bay, very few fish dealers have cold storage facilities and majority of the fishermen do not have access to them. Similarly, most fishermen and many fish dealers are not keen to engage in other preservation options available for example smoking and/or salting of fish. Fishermen often loose large quantities of fish through spoilage and are always in a hurry to dispose their catch quickly.

Impacts of open access to the resource

The most significant market failure that has affected resource use and management include lack of property rights leading to open access, assumed lack of markets, spill-overs that are not traded in the market, high transaction costs, public goods as a characteristic of the fisheries resources, market imperfection in the form of lack of competitors in the use of bycatch, and uncertainty and risk aversion.

High cost of gillnets

Big gillnets cost between Kshs. 10,000 and Kshs. 25,000 each (according to local sources). This amount is by all means too high to an artisanal fisherman who earns between Kshs. 100 – 500 a day. Therefore destruction of a single gillnet causes panic to the fishermen!

ECONOMIC ACTIVITIES PERFORMED BY FISHING HOUSEHOLDS

The fishing households in Malindi-Ungwana Bay have partially diversified their sources of income in order to maximise their welfare. However, the income obtained from the different sources is too low limiting majority of the households to live below the poverty line. Table 2 below shows the percentage contribution of the different economic activities to the fishing households.

Table 2: Matrix of economic activities peculiar to fishing households

Location	*Fishing*	*Fish trade*	*Small business*	*Peasant farming*	*Casual jobs in trawlers*	*Boats making*	*Makuti making*
Malindi	*70%*	*13%*	*3%*	*8%*	*3%*	*3%*	-
Ngomeni	*90%*	*6%*	-	*4%*	-	-	-
Kipini	*60%*	*27%*	*9%*	-	-	-	*4%*

Matrix of economic activities peculiar to fishing households

From table 2 above, it is evident that fishing is the lifeline of these households followed by fish trade. Problems in the fisheries sector therefore impacts adversely on the welfare of these households. This has led to increased fishing effort that has resulted in unsustainable exploitation of wild fish stocks. This is the case at Ngomeni and Kipini where artisanal fishing is the main source of employment for the school leavers and dropouts. Since many parents cannot afford school fees for their children, they often take them to the Islamic schools ('madrassa') where they acquire some basic Islamic education.

ANALYSIS OF COSTS AND BENEFITS OF PRAWN TRAWLING IN THE MALINDI-UNGWANA BAY

The excessive bycatch and discards threaten sustainability of fish stocks, promote juvenile wastage and are therefore a likely cause of long term food insecurity to the coast region. Conflicts between stakeholders are associated with the high costs of resolution. The expenditure on conflict resolution could be channelled into other research and development projects to maximise welfare. Occasional destruction of gillnets by trawlers compel artisanal fishermen to sacrifice their consumption in order to invest in buying new gillnets. This applies even when a fisherman is compensated as compensation comes much later and the fisherman has to continue fishing. Habitat modification which impacts on productivity, reduced biological diversity, is a threat to the artisanal fishermen who risk to suffer from reduced income due to declining fish catches resulting in increased incidence of poverty among the artisanal fishers. There are costs associated with production and consumption opportunities foregone. In addition, the opportunity costs associated with not putting the resource in alternative uses.

Approximately 708 Kenyan citizens are earning direct income from employment and activities related to prawn trawling (Table 3). In addition, these people support some 4248 dependents. Therefore, approximately 4956 people depend on prawn trawling for livelihood.

Contribution of Revenue to the Government:

Contribution to the government annually is in the form of export levy, licenses, port handling charges and other charges. Trawler owners have donated a motor vehicle to the Malindi fishermen's cooperative society to facilitate fish marketing.

Table 3: Projected number of people dependent on prawn trawling in the coast

Type of work	Number employed	Estimated number of dependents	Total dependent population
Crew	77	462	539
Quality controllers	4	24	28
Fish shop attendants	7	42	49
Other facilitative services	100	600	700
Casual staff	20	120	140
Fish mongers/traders	500	3000	3500
TOTAL	708	4248	4956

CONCLUSIONS/RECOMMENDATIONS

The results indicate that fishing effort, especially the number of fishers, type of gear, and net mesh size are important determinants of fish harvest rates, and habitat modification. The production, sale and use of destructive fishing gears should be regulated. It may be necessary to introduce an incentive structure to promote the production and use of appropriate technology. Those who produce and use destructive fishing technology should be completely banned from doing so. It is recommended that, special credit schemes should be established to assist those who want to acquire appropriate fishing gears.

Fishermen are forced by a number of reasons to use efficient but destructive fishing techniques. The appropriate fishing gears such as gillnets, are more expensive and only a few fishermen can afford them. In addition, demand for both mature and juvenile fish is very high in the local market. Interventions should therefore target the size of fish traded in the market. It is also evident that fishermen do not have incentives to use appropriate fishing techniques because the fisheries are characterized by open access and there are logistical constraints hindering the enforcement of existing regulations.

Results have further indicated that direct contribution of prawn trawling to the government is so minimal since it currently contributes only about Ksh.2 million. This should be addressed so that the positive contribution of this important player is felt by all the affected parties especially the government, the local community, and the trawler owners. If the export levy is raised to 10%, part of this should be taken back to the local community to improve their living standards. Therefore, it is recommended that export levy be raised on prawn export.

HEAVY METAL CONCENTRATIONS IN SEDIMENTS AND BIOTA IN THE UNGWANA AND MALINDI BAYS

Daniel Munga

INTRODUCTION

There are two major rivers that discharge through estuaries into the Ungwana and Malindi Bays, R. Tana and R. Sabaki, respectively, which are sources of high volumes of sediments. Estuaries play an important role in the pathways of heavy metals in the aquatic environment. The mixing of freshwater from land-sources and seawater results in brackish water of variable salinity, and other physico-chemical parameters, such as pH, DO, Eh and conductivity. Mixing results in a number of processes which influence the pathways and concentration of metal elements in natural water, and they include precipitation of dissolved organic and inorganic materials, coagulation, partitioning into particulates and colloids, desorption/sorption, sedimentation and resuspension. Indeed, mixing processes and net sedimentation of suspended particulate matter limit the transport of heavy metals beyond the estuary which may act as a sink for the contaminants. While the form and concentrations of the metals in natural water may determine their bioavailability, other factors such as feeding habits may greatly influence interaction with biota.

OBJECTIVES OF THE STUDY

The objectives of the present study were to establish concentration levels of the heavy metals copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), cadmium (Cd) and lead (Pb) in surficial sediments and selected organisms, especially the commercially important prawns, and assess the implications of the levels of the contaminants to pollution in the Ungwana and Malindi Bay complex.

STUDY METHODS

Sampling stations were located along 5 transects, namely Mambrui, Kalifi, Sadani, Tana and Kipini. Stations were located at 1.5 nm, 3.0 nm, 4.0 nm and 5.0 nm from the shoreline (Fig. 1.1). Sampling was carried out monthly from June 2001 to May 2002. For the purposes of this report data for the months of October to December 2001 were considered.

Sediments were obtained and wrapped in labelled polythene bags and stored in a deep freezer at -5 to -20 °C. In the Laboratory the samples were air-dried and homogenised with a pestle and mortar. Samples of whole sediment and sediment size fraction <125 μm, were separated by sieving, and taken for analysis. Prawn (*Peneas monodon*) and biota samples obtained from the trawler were deep frozen to await analysis in the laboratory onshore.

Analysis of Samples

Accurately weighed dried sediment samples (0.2 g) were digested in sealed teflon containers at 125 °C for 2 hrs. The digestion mixture was then cooled and 2 ml of hydrochloric acid added to dissolve the salts. The resultant mixture was made to volume in a 50 ml volumetric flask with distilled water. Similarly, dried samples of biota were digested with hydrochloric acid, nitric acid and perchloric acid. Elemental analysis was performed by atomic absorption spectrophotometry with air-acetylene flame (Varian Spectra AA10).

Data Quality Control

Data quality control was carried out by analysing certified reference material, Marine Sediment standard 140 obtained from the International Atomic Energy Agency. For the 6 metals analysed the difference between the measured and certified values was less than 10 %. The procedure was considered satisfactory and observed values were accepted without corrections.

RESULTS AND DISCUSSION ON LEVELS OF HEAVY METALS IN UNGWANA/MALINDI BAY

Heavy Metals in Sediments

Concentrations of Cu, Fe, Mn, Zn, Cd and Pb were reported in whole sediment and in <125 μm sediment grain size fraction. Spatial distribution of the concentrations was considered on the <125 μm sediment size fraction. The results presented are composed of mainly data for December, but also include some data for October and November 2001.

Cu concentrations ranged from 2.5 to 45.3 µg g^{-1} dry wt in whole sediment, and 2.4 to 44.3 µg g^{-1} dry wt in <125 µm sediment size fraction. The distribution of Cu in whole sediment and <125 µm sediment size fraction is graphically presented in Figure 1. On average the highest concentrations occurred along the Mambrui transect.

Concentrations of Fe varied from a minimum of 0.5 to a maximum of 65.9 µg g^{-1} dry wt in whole sediment and 26.7 to 94.7 µg g^{-1} dry wt in the <125 µm sediment size fraction. On average, the highest concentrations occurred along the Kipini transect, particularly 1.5 and 3.0 nm from shore (Fig. 2).

The concentration of Zn ranged from 35.9 to 426.5 µg g^{-1} dry wt (mean 69.9 – 294.4 µg g^{-1}) in whole sediment and 59.1 to 500 µg g^{-1} dry wt (mean 150.6 – 331.4 µg g^{-1}) in <125 µm sediment size fraction. Concentration levels were generally comparable along the Mambrui, Tana and Sadani transects. With the exception of the Sadani transect, relatively higher Zn concentrations were found 1.5 nm from shore (Fig. 3).

Concentrations of Cd varied from 2.3 to 32.1 µg g^{-1} dry wt in whole sediment (mean 4.0 – 14.8 µg g^{-1}) and 2.5 to 31.0 µg g^{-1} dry wt (mean 8.9 – 15.8 µg g^{-1}) in <125 µm sediment size fraction. The Mambrui transect had the highest concentration, closely followed by Kipini (Fig. 4).

The concentrations of Pb ranged from 25.5 to 170.9 µg g^{-1} dry wt (mean 63.8 – 111.7 µg g^{-1}) in whole sediment and non-detectable to 123.4 µg g^{-1} dry wt (mean 37.0 – 76.1 µg g^{-1}) in <125 µm sediment size fraction. The highest mean concentration occurred along Mambrui followed by the Kipini transect (Fig. 5).

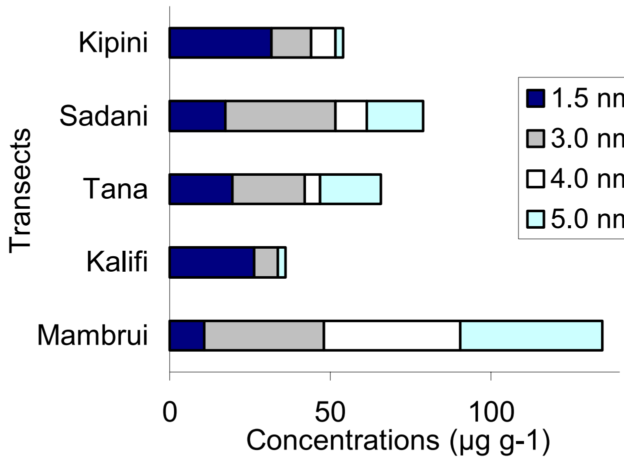


Fig. 1: Distribution of copper in <125µm sediment size fraction

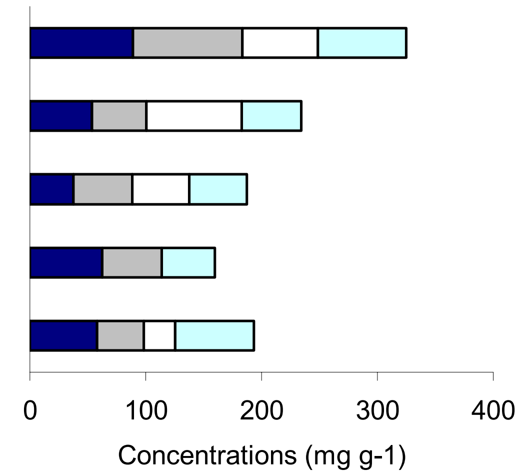


Fig. 2. Distribution of iron in sediments

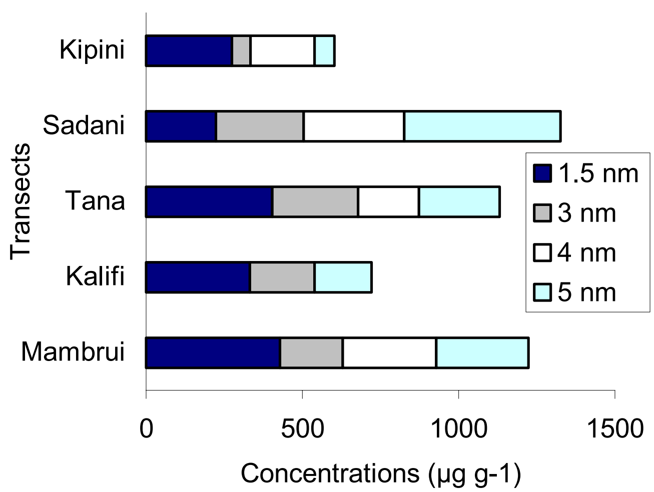


Fig. 3: Distribution of zinc in sediments

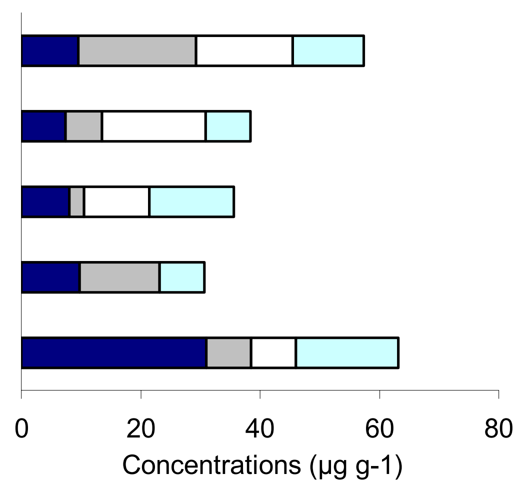


Fig. 4. Distribution of cadmium in sediments

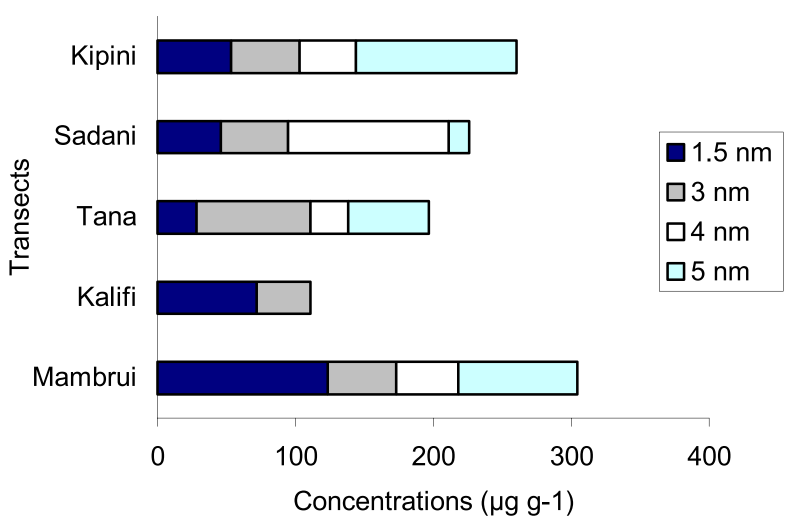


Fig. 5. Distribution of lead in sediments

Correlation and Principal Components Analysis

To elucidate relationships among the elements, correlation coefficients were determined and the concentration data subjected to Principal Components using STATISTICA Kernel release 5.5A ’99 Edition (StatSoft Inc., 2002).
Cd was significantly correlated to Pb (Table 1). Correlations between Cd and Fe and Pb and Fe were appreciable, but not significant at $p < 0.5$.

Table 1. Correlation matrix (Highlighted correlation is significant at p<0.05)

	Cu	Fe	Zn	Cd
Fe	-0.24	1		
Zn	0.29	-0.33	1	
Cd	-0.28	0.45 p=0.054	0.04	1
Pb	0.02	0.44 p=0.059	0.02	**0.53 p=0.021**

Table 2. Factor loadings of principal components

	Factor 1	Factor 2
Cu	-0.46	**0.58**
Fe	**0.81**	-0.09
Zn	-0.33	**0.77**
Cd	**0.79**	0.31
Pb	**0.70**	0.51
Eigenvalue	2.08	1.29
% of total variance	41.7	25.7

Two principal components were extracted from the concentration data accounting for 67.4 % of the variance (Table 2). Factor F1 accounted for 41.7 % of the variance and was characterised by high positive loadings of Fe, Cd and Pb. In nature Cd exists as a sulfide salt and is frequently associated with Pb ores (EPA, 1976). The association of the two elements with Fe signifies their common (terrestrial) source, which is patently alluvial. Factor F2 accounted for 25.7 % of the variance and was characterised by a high positive loading of Zn and moderate loading of Cu. Thus, this factor was associated with the common mineral source of the two elements. A plot of the factor loadings clearly shows the two groups of related elements (Fig. 6).

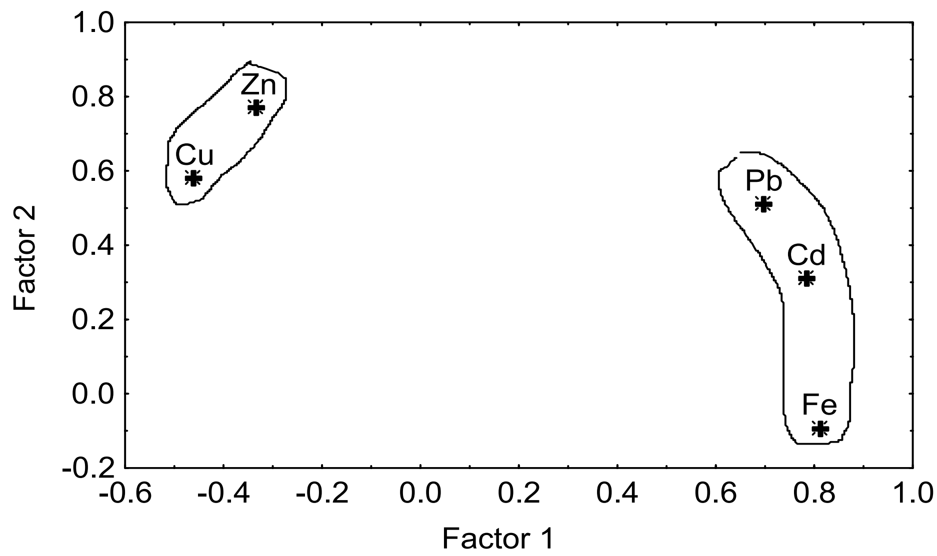


Fig. 6. Plot of factor loadings on metal concentrations

ASSESSMENT OF LEVEL OF HEAVY METAL POLLUTION IN THE UNGWANA / MALINDI BAY

The concentrations of Cu, Fe, Zn, Cd and Pb in sediments along the Kenya coast from previous investigations are presented in Table 3. Also included are reported levels from the NE Pacific which is considered to be among the least polluted areas in the world and is thus, used as a reference (Everaarts and Nieuwenhuize, 1995).

Table 3: Comparison of Cu, Zn, Cd, Pb (µg g^{-1} dry wt) and Fe (mg g^{-1} dry wt) in sediments

Location (Ref.)	Cu	Zn	Cd	Pb	Fe
Coastal zone NE Pacific (1)	4.3 - 101	33 – 124	0.38 - 1.30	7.0 - 12	-
Continental slope and coastal zone, Kenya (2)	3.0 – 42	2.0 – 117	0.01 - 0.34	0.5 - 15.8	4.0 - 69
Makupa and Kilindini creeks (3)	5.5 – 114	< 200 – 1429	< 10 - 13	-	< 20 - 27.7
Mombasa inshore waters (4)	1.0 - 1177	3.0 – 283	-	1.0 - 427	-
Ungwana and Malindi Bays (5)	6.4 – 24.1	69.9 – 294.4	4.0 – 14.8	63.8 – 111.7	10 – 81.3

References:
1. Harding & Goyette (1989)
2. Everaarts & Nieuwenhuize (1995)
3. Kamau (2001)
4. Williams et al. (1997)
5. Present study.

In general, the results indicate elevation of concentrations of Zn, Cd, Pb and Fe compared to NE Pacific as well as earlier findings by Everaarts and Nieuwenhuize. In descending order of relative degree of elevation Cd > Pb > Zn > Fe. The observed elevated metal concentrations compared to previous findings by Everaarts and Nieuwenhuize, with R. Sabaki estuarine sediments as the reference, can be attributed to high volumes of sediments that were discharged into the bay during the El nino deluge in 1997/98. While the concentrations may be within proposed limits (Cu 400 $\mu g\ g^{-1}$, Zn 2500 $\mu g\ g^{-1}$, Cd 30 $\mu g\ g^{-1}$) (Kamau, 2001), possible remobilization of the elements in the sediments and water column, resulting in enhanced bioavailability is a matter of concern.

HEAVY METALS IN PRAWNS

The concentrations of Cu, Fe, Mn, Zn, Cd and Pb in muscles of samples of penaeid prawns obtained from Mambrui, Kalifi and Kipini are presented in Table 4.

Table 4. Metal concentrations in prawn muscles

Station	Date	Metal	No. of Samples	Metal concentrations ($\mu g\ g^{-1}$ dry wt)			
				Max	Min	Mean	SD*
Mambrui	23/4/02	Copper (Cu)	10	6.34	1.98	4.65	1.37
		Iron (Fe)	10	29.50	10.52	17.63	5.74
		Cadmium (Cd)	10	0.37	0.09	0.19	0.07
		Lead (Pb)	10	2.11	1.08	1.63	0.27
		Manganese (Mn)	10	3.31	0.81	1.74	0.76
		Zinc (Zn)	10	55.14	8.99	36.62	12.24
Kalifi	25/4/02	Copper (Cu)	10	5.63	3.08	4.14	0.90
		Iron (Fe)	10	35.08	13.37	20.63	7.86
		Cadmium (Cd)	10	0.39	0.18	0.23	0.07
		Lead (Pb)	10	2.36	1.85	2.12	0.16
		Manganese (Mn)	10	2.53	0.78	1.88	0.48
		Zinc (Zn)	10	43.35	24.68	33.20	5.98
Kipini north	26/4/02	Copper (Cu)	10	2.79	1.51	2.17	0.43
		Iron (Fe)	10	20.99	10.97	15.90	3.39
		Cadmium (Cd)	10	0.48	0.09	0.20	0.11
		Lead (Pb)	10	2.44	1.33	1.78	0.39
		Manganese (Mn)	10	2.82	1.78	2.09	0.31
		Zinc (Zn)	10	36.03	19.98	28.20	4.71

* standard deviation.

The World Health Organization and Food and Agriculture Organization (WHO and FAO) determined a maximum tolerable weekly intake of Cd of 7 μg kg^{-1} (acceptable daily intake, ADI of about 60 μg $person^{-1}$ day^{-1} for a 60 kg person). The FDA suggested an ADI of 55 μg $person^{-1}$ day^{-1} for a 60 kg person (FDA, 1993a). Considering the maximum concentration encountered in the present study of 0.48 μg g^{-1}, and adopting the FDA estimated average crustacea consumption (in the USA) of 17 g wet wt day^{-1}, the resultant Cd intake would be 8.2 μg $person^{-1}$ day^{-1}, which is way below the maximum tolerable weekly intake.

The recommended provisional tolerable total intake level (PTTIL) for Pb by FDA is 75 μg day^{-1} for adults (FDA, 1993b). At the average crustacean consumption of 17 g wet wt day^{-1}, the expected Pb intake would be much less than 41.5 μg day^{-1}. Thus, with reference to the WHO/FAO and FDA guidelines, the average levels of Cd (0.19 – 0.23 μg g^{-1} dry wt) and Pb (1.6 – 2.1 μg g^{-1} dry wt) found in prawn muscle samples are acceptable.

CONCLUSION

The study established the distribution of the heavy metals Cu, Fe, Zn, Cd and Pb in surface sediments in the Ungwana and Malindi Bays nearshore areas. All the elements, with the exception of Cu, showed varying degrees of elevation, with Cd being the most and Fe the least elevated compared to previously reported concentrations and levels in the NE Pacific. The concentrations found are, however, within proposed environmental limits.

The concentrations of Cu and Zn in prawn muscles were lower than previously reported. Cd concentrations were lower than previously reported, but higher than in the NE Pacific. Pb concentrations were higher than both previously reported and NE Pacific levels. Fe and Mn were generally lower than previously reported results. With reference to WHO and U.S. FDA guidelines, the concentration levels of Cd and Pb in the prawn muscles are within acceptable safe limits.

REFERENCES

Everaarts J.M. & Nieuwenhuize, J. 1995. Heavy metals in surface sediment and epibenthic macroinvertebrates from the coastal zone and continental slope of Kenya. *Marine Pollution Bulletin* **31**, 281 – 289.

EPA 1976. Quality criteria for water. U.S. Environmental Protection Agency. 256p.

FDA 1993a. Guidance document for cadmium in shellfish. U.S. Food and Drug Administration Centre for Food Safety and Applied Nutrition, Washington, D.C.
Web: http://www..cfsan.gov/~frf/guid-cd.html

FDA 1993b. Guidance document for lead in shellfish. U.S. Food and Drug Administration Centre for Food Safety and Applied Nutrition, Washington, D.C.
Web: http://www.cfsan.gov/~frf/guid-pb.html

Harding, L. & Goyette, D. 1989. Metals in north-east Pacific coastal sediments and fish, shrimp, and prawn tissues. *Marine Pollution Bulletin* **20**, 187 – 189.

Kamau, J.N. 2001. Heavy metals distribution in sediments along the Kilindini and Makupa creeks, Kenya. *Hydrobiologia* **458**, 235 – 240.

StatSoft, Inc. 2002. Electronic statistics textbook. Tulsa, OK : StatSoft.
Web: http://www.statsoft.com/textbook/stathome.html

Williams, T.M., Rees, J.G., Ferguson, A., Herd, R.A., Kairu, K.K. & Yobe A.C. 1997. Metals, petroleum hydrocarbons and organochlorines in inshore sediments and waters of Mombasa, Kenya. *Marine Pollution Bulletin* **34**, 570 – 577.

WHO 1989. Guidelines for the study of dietary intakes of chemical contaminants. In *Global Environmental System*, WHO, Geneva, Switzerland. 49p.

IMPLICATIONS OF SHORELINE CHANGE ON THE UTILISATION AND MANAGEMENT OF THE MALINDI-UNGWANA BAY SHORELINES

K. Kairu, P. Abuodha, H. Ong'anda

INTRODUCTION

The coastal zone in Malindi has suffered periods of severe erosion interspaced with periods of rapid shoreline build up. The dynamic nature of the coastal zone is a major concern to coastal developers. A stakeholders' workshop organized in Malindi deliberated on the problem and recognized the need for guidelines on development of newly accreted areas.

OBJECTIVES

The objective of the present study was to develop a clear understanding of the present and feature evolution of the low-lying environments of Malindi and South Ungwana Bay.

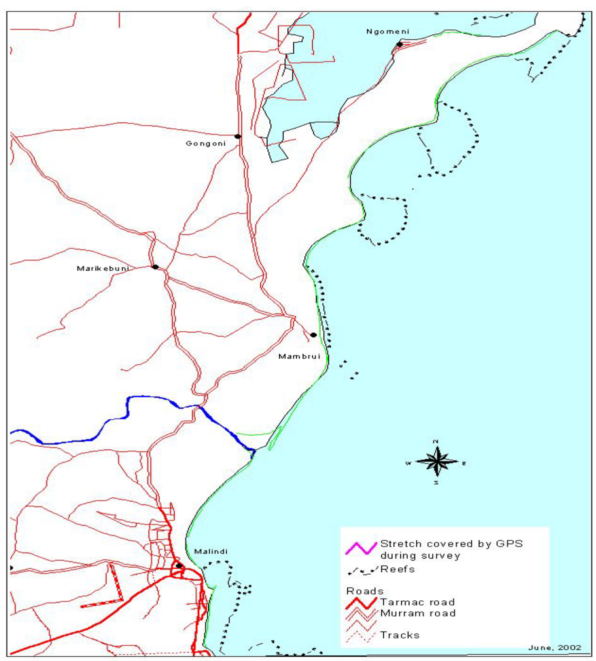


Fig: Coastline, Ungwana-malindi area

The main study area fig.1 runs from the Leopard Point south of Malindi northward to Ngomeni. The southern sector from Mayungu to the Vasco da Gama point consists of short steep beaches isolated from one another by rocky promontories that jut into the sea and trap pocket beaches that are fronted by wide wave platforms. North of the Vasco da Gama headland to the shoulders of Ras Ngomeni, the lower coastal plain comprises of wind blown sands and lagoonal deposits that becomes an expansive environments over the 0-10 m coastal terrace.

GEOLOGICAL SETTING

The western edge of the 0-10m terrace complex swings gradually westward north of Malindi and is recognized as a ridge at the end of the lower coastal plain 1km west of Mambrui and runs due north parallel to the road. Exposures are observed at the Golf course and the Sabaki bridge. Beaches in this sector are flat and terminate offshore on a NS running trending wave cut platform observed at the beach foot. The Vasco da Gama and the Ras Ngomeni headlands are relict features of a fossil reefal feature that stretched from Malindi to Ungwana bay (fig. 1). Wave refraction on offshore highs belonging to this relict system has a strong structural relationship with beach evolution and occurrence of the caspate shorelines observed in Mambrui.

The Sabaki mouth is a shallow feature rarely exceeding 2m in depth. Between 1986 and the present the estuary has recorded periodic migration within the bay. Similar migration is recorded on a map of 1896. Malindi shorelines appears to have experienced similar episodic erosion in the 1960's, a sea wall stretched from the Fisheries Department through the Malindi port to the Hotel area. Remnants of this wall is visible in front of the hotels and at the Fisheries Department. The erosion persisted until the 1970 when a new sea wall was constructed. The wave energy in the beach area in the 1960 was typical of an eroding environment Plate I. Isolated reefal structures, the Giffon patches, occur offshore in front of Malindi bay. They merge southwards to form the North reef. These features represent a transition from the Sabaki siliclastic beaches to the silver sands carbonate beaches. Beaches in this sector are dominated by short coral cays. Sheshale bay and the other small bays occur where these reefal highs have been breached and suitable environments for beach accumulation has evolved.

RESEARCH METHODS

Two approaches were used in the study. A desk study to collate available information including published information and project reports. This was augmented by a quick appraisal study to bridge information gaps in the absence of differential GPS. Standard GPS traverse survey was adopted for the field study. Shoreline change was computed from bench marks existing in old maps, reference to known shore positions and datable historical attributes on the shoreline. To map the present shore position a 12 channel GPS was used. Shore positions established on the 1995 Survey Map of Kenya and datable fixed shore positions were used to provide time information. Grain size analysis was used as indicators of source and dispersal of sediments.

OBSERVATIONS AND RESULTS

The Environmental Geology of the Coastal area

The lower coastal plain south of Malindi is dominated by accumulation of unconsolidated beach sands overlying 0-10 coastal terrace. From Malindi to Mambrui, deltaic deposits comprising of beach sands overlain by windblown deposits dominate the lower coastal plain. The structure and near surface stratigraphy shown in `Fig.2'.

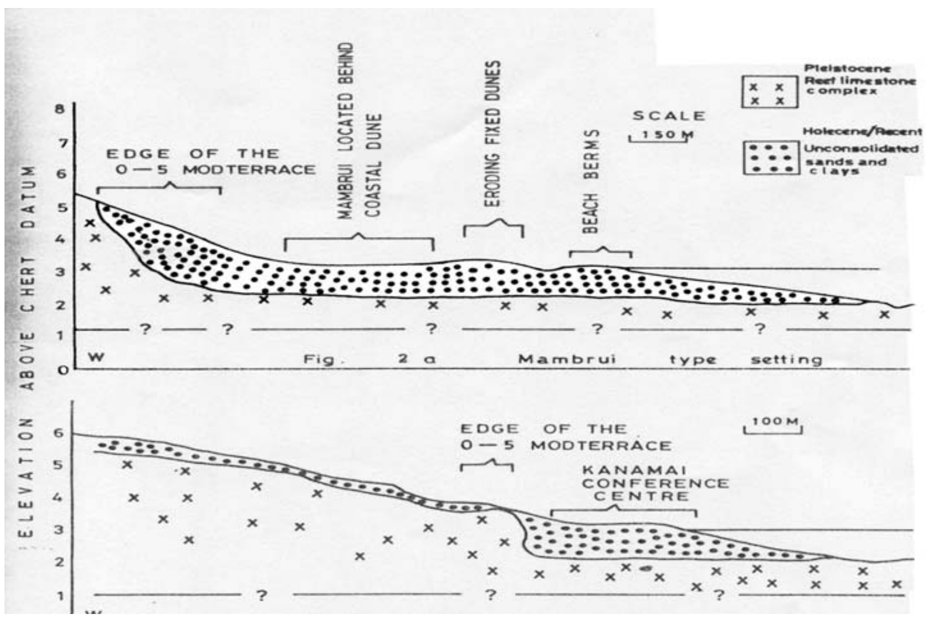


Fig.2 Stratigraphy of Malindi – Ngomeni area

The surface geology comprises of an unconsolidated sequence of beach sands overlain by loose windblown deposits. North of the Ngomeni headland the stratigraphy is variable and the geology becomes more complex. Poorly consolidated beach rock is overlain by a sequence of peat and clay overlain by windblown sands. At the San Marco area, a discordant course grained beach rock overlain by windblown sands is observed. The course grained sands give way further south east to an intercalating sequence of mangrove peat with pottery horizons overlain by the NNE-SSW trending dunes 50 meters north west of San Marco. A clear indication that mangroves of Ungwana bay extended further south in Holocene. The intercalating sequence of peat and beach rock is overlain by the windblown sands of the Ngomeni dunefields that link the land to the Ras Ngomeni headland, a relict feature observed offshore from Ras Ngomeni to Mambrui (Fig.3). The eroding area on the Ras Ngomeni headland (Fig.3) falls on the outside meander of the Rasini creek. Sand eroded from the headland is deposited on sandbars growing north east of San Marco (Fig.3). Growth in the sand bar system has shifted southward with the erosion of the Ngomeni beach.

Erosion of low lying coastal areas

The Mambrui-Ngomeni shoreline is a caspate shoreline Fig.1 mapped as accreting in 1956 (Thompson 1956). Surveys dating back to 1986 document persistent erosion of the Ngomeni shoreline. This is supported by the current survey (Fig.3) which indicates a net loss of 0-100 meters in front of the casps and an accretion on the NE flanks of the headland Fig.1. A long-term erosion trend is documented further north in Kipini area where ancient villages have been inundated by the sea.

Plate1. Malindi of 1960

Accretion of the Deltas

The narrow intertidal zone 500-2000 meters result in high wave energy. Tidal influence on the estuary is indicated by land oriented swash and Mouth bars characteristic of wave and tide dominance. Accretion of the delta is recorded since 1896. A new dune ridge (plate III) recorded between 1986-1996 is indicative of the progradation.

Rapid progradation of the delta front with erosion reported in adjacent delta flanks in north Mambrui and south Malindi is observed in all previous surveys. The current survey (Fig.1 and Fig.3) gives a clear indication of the progradation in Malindi area (plate II) and erosion in north Mambrui and Ngomeni.

Historical Records

Settlements dated between 11-18th Century located on the lower coastal plain in Kipini, Ngomeni and Mambrui have lost part or the whole of the beach front. Mambrui in the early 1980 had the front row flooded by wind blown dunes. The evolution of a new beach ridge by 1996 trapped the sands and stopped the flooding. In Malindi between the Vasco da Gama headland and the Malindi Port, settlements older than 14th and the 18th Century are still intact. Beachfront environments in Malindi in 1960 were dominated by erosional environments requiring protection of the beach road (Plate I). In the 1970's this shoreline suffered severe erosion necessitating the erection of new coastal defense plate III. The period dating from the construction of the sea wall has been preceded by rapid accretion of Malindi bay estimated to increase from zero at the Vasco da Gama headland to over 800 meters at the Sabaki estuary (Fig.1). Rapid progradation terminates at Mambrui.

The area between the active shoreline and the fixed shoreline is dominated by aeolin process (Plate III). A beach ridge fronting the active shoreline is fixed by *Ipomea Pescaprae* in the southern sector and by a beach grass on the higher active beach ridges of the northern sector. A northwest migrating dune front similar to a small one in front of Malindi (Plate III) is observed north of the Sabaki delta. The delta front is however dominated by NE trending beach ridges excavated by the wind to the water table. North of Mambrui dune evolution stops to reappear in Ngomeni, a clear indication of restriction of active deltaic growth to the Sabaki delta front. Reworking of the dunes and loss of stabilized shorelines older than 14th Century is noted north of Mambrui. The Ngomeni dunes have NNE-SSW trend in line with the tombolo and there are no modern analogues. This is indicative that Ngomeni dune evolution had a different driving mechanism from the Mambrui dune field which have a N-S trend.

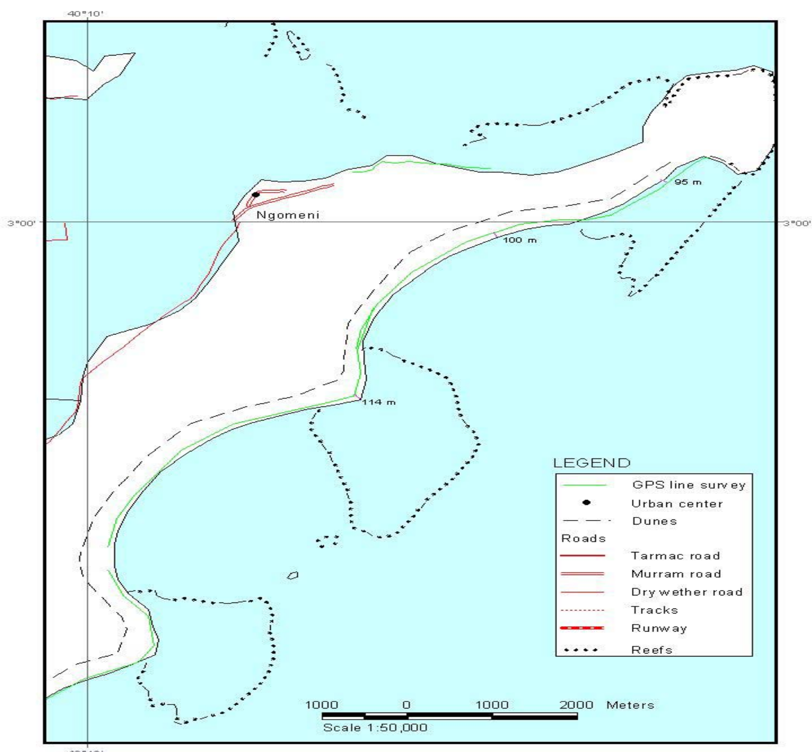


Fig.3 Mapped eroding areas showing relationship to offshore structures

DISCUSSION

The lower coastal plain in Malindi dates back to the 14th Century. The old Swahili towns of Malindi, Mambrui, Ngomeni and Ungwana were developed wholly or partly on this lower coastal plain and date back to the same period and some to the 11th Century. Apart from Malindi that has been spared from erosion and loss of part of the older settlements, Mambrui, Ngomeni and Ungwana in Kipini have lost large areas of the beach front environments that are documented in history of human habitation in the coastal area between the 11th and 20th century. Erosion is documented in Malindi. In the pre 1960 period and in the

1970's that necessitated coastal protection. This was followed by rapid accretion of the lower coastal plain and the extensive beach ridge system of the Sabaki delta. Positive accretion is documented in the new field surveys in the Malindi Mambrui area. However in the other areas, the survey recorded erosion of modern 11th and 14th century settlements in Kipini. The eroding environments falls on the lower coastal plain, an extensive coastal area that extends from Malindi to Lamu, a width of over 40 km in Ungwana bay and measures less than a few hundred meters south of Malindi. The evolution and natural stabilization of a new beach ridge by beach grass south of Mambrui in the 1990's resulted in retention of large volumes of sand in the north Sabaki dune fields. This appears to have temporarily arrested the flooding of Mambrui by windblown dunes documented by 1986. The Ngomeni setting on the outside meander of the Rasini creek and exposure to wave action from the open sea increase vulnerability of the area. This has contributed significantly to land loss in Ngomeni. Eroded sand is deposited in the growing longshore and offshore bars north of the creek. Persistence of erosion on the eastern shore of the Ngomeni headland will eventually result in complete breaching of the tombolo. The event of this will induce a cataclasmic change in the circulation pattern of Malindi bay. With possible dispersal of Sabaki sands beyond Ngomeni completely altering the Malindi Bay sediment budget.

These changes could induce and accelerate erosion in Malindi-Mambrui area. A reduction in the sediment yield from better land management and damming of the Sabaki would further alter the Malindi bay sediment budget. Though Malindi Bay has recorded gradual accretion at least since 1896. Adjacent areas south of Malindi and north of Mambrui are reporting gradual erosion in the lower coastal plain. Unconsolidated windblown sands and beach deposits that dominate the lower coastal plain are readily available to erosion.

The Sabaki delta front is a sensitive environment supported by high sand nourishment by the Sabaki and the fixing of the sediment by natural processes of the Malindi bay. Interference with this process threatens stability of the bay. Recorded erosion in Ngomeni and threat by sand flooding in Mambrui area indicative of possible consequences of instability in the bay. The newly built up phase of the delta dates back to the 1970's which is an extremely short period in determining the stability of the coastal area. Development activity in the lower coastal plain should therefore be restricted to provide a buffer to shoreline change.