KENYAN-BELGIAN COOPERATION IN MARINE SCIENCES

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KENYAN - BELGIAN PROJECT IN MARINE SCIENCES

SECOND QUARTERLY REPORT

April - June 1987

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SECOND QUARTERLY REPORT

April - June 1987

ACKNOWLEDGEMENTS

First we like to thank the Kenyan and Belgian Governments and the authorities of KMFRI, who gave us the possibilities to continue this Kenyan-Belgian Project in Marine Sciences.
But we like to thank especially the General Administration for Cooperation and Development - Ministry of Foreign Affairs - Belgium for providing fellowships for several scientists of KMFRI for specialisation in Belgium (see chapter 4).
We are also grateful to the National Fund for Scientific Research - Belgium, for the grants offered to Belgian Experts in order to cover travel and accomodation expenses. Thanks to this financial support their research programs in collaboration with the Kenyan counterparts were continued. They also brought extra equipment and specific scientific literature with them for which we thank the Belgian Universities, especially the Free University of Brussels and the University of Antwerp.
We are also very grateful to UNEP and UNESCO - IOC for the expert missions they offered Prof. Polk, Mr. Pissierssens and Mr. Onyango. Prof. Polk visited the Universities and Institutions in Marine Sciences in the East African countries and West Indian Ocean Islands (see program included). The report on this mission has been introduced to UNEP - Nairobi. Mr. Pissierssens and his Kenyan Counterpart Mr. Onyango introduced their report on the feasibility study they made for UNESCO - IOC for a computer network for a Documentation Centre and Scientific Data Base for East Africa.
Those two missions gave also the opportunity to the KBP to establish contacts in the East African Region in order to develop the present project into a more Regional Project on Marine Sciences.

INTRODUCTION

Besides the scientific reports of the scientists of KMFRI working in the KBP, several publications have been submitted or are in preparation which shows that the research programs are going on continuously and are giving satisfactory results. Once the data of the different research fields are compiled by computer, an ecological model of the ecosystems can be worked out.
Before a management of Coastal Areas and Mangrove systems can be elaborated, which is one of the aims of the project, the different aspects of the ecosystems have to be studied. Knowledge of the different components of such ecosystems in function of tidal and seasonal effects and of the influences of the components on each other, will be compiled in a model and form the basis of management proposals.

1. WORKPLANNING

Concerning the sampling schedules included here, the following samplings could not be done :

- April 2 : only one canoe outboard engine was working
  - 8 : Maumba boat was out of order
  - 17 & 20 : official holidays
  - 27 & 28 : no transport available - Landrover out of order

- May 4 to 9 : Landrover was out of order
  - 11 & 20 : Maumba boat was still out of order
  - 20 to 22 : Malindi trip cancelled due to financial-administrative problems of KMFRI
  - 21 & 22 : sampling in Tudor Creek postponed due to heavy rains
  - 26 & 27 : 24-h cycle in Gazi had to be cancelled because the field equipment was not complete

- June 2 & 3 : Landrover was at garage for servicing
  - 12 : only one outboard engine was working
  - 15 to 19 : no sampling could be done at Tudor Creek due to a wall which has been built around the Institute compound, so that canoes, engines and sampling equipment could not be transported anymore to the beach nearby.

- June 22 : Canoes and engines have been transported to Bahari Club in order to continue sampling at Tudor Creek. Unfortunately, now transport by car is also needed for these samplings (for the research officers, the technicians and equipment).
  - 23 - 25 : Malindi trip was cancelled due to administrative reasons at KMFRI.

2. VISITS TO THE PROJECT

2.1 Visiting Experts

* Weston, J. Friends World College - Machakos
  Oyster culture, Beach Erosion by biological and physical effects
  April 23 - June 30

* Vanden Berghe, W. Free University of Brussels
  Computer Section KMFRI
  April 13 - May 21

* Revis, N. Free University of Brussels
  Zooplankton
  April 26 - July 24

* Jouk, Ph. University of Limburg
  Meiobenthos
  May 25 - June 25

* Prof. Dr. Decleir, W. University of Antwerp
  Ecophysiology
  June 4 - June 18

2.2. Visits to the Kenya Marine & Fisheries Research Institute and the KBP

* De Vos, D. - Reporter for "Nord Sud Magazine of International Cooperation"
  March 29 - April 4
* Mrs. Mwango & Mrs. Thitac - Delegation of the Office of the President, Science Secret. NCST
  April 14
* Naivasha Wildlife and Fisheries Institute - April 12 - 16
  Training Course of Assistant Fisheries Officers.

* Mrs. Wanjau - Office of the President, Directorate of Personnel Management
  April 23 - 25

* Rees, T. and Wieninger, R. - "Bio-Algeen Products" for Nature and Environment
  Interested in commercialisation of the oyster culture
  May 4 - 5

* Delegation of Moi University - May 7
  Students of Fisheries Managment Department

* Delegation of Nairobi University - June 27
  Students of Zoology Department

3. ONGOING RESEARCH

This chapter includes only a survey of the research work. The scientific reports concerning the different research programs are enclosed in the Annexes (chapter 5).

3.1. Oyster Culture

Research on growth rates of the oyster spat and on competition between oysters and other marine organisms is still going on. Different materials are tested to catch spatfall :

- coconut shells covered with mixture of marine cement and chalk
- roofing tiles with and without the same covering mixture
- frame of coconut strings, covered with a thin layer of marine cement, hanged in between the oyster strings to provide shade

This collection of spatfall is needed to provide stock of young oysters for culture, as wild oysters can be soon depleted.
More racks have been build to continue the culture of the young oysters settled after the rainy season of last year (may - june 1986).
However, after this rainy season many of the oysters on the strings were covered by fouling organisms : spat of oysters, other bivalve species, barnacles,...
These additional organisms not only create competition for space and nutritive elements, but very often also death of the cemented oysters which are not able anymore to open their shells for feeding filtration. As competition for space is one of the factors behind culturing oysters away from their natural settlement sites, other culture possibilities have to be tried out such as building the racks away from collecting areas in a bay where less or no wild oysters are growing, or as culturing oysters in hanging nets.
Besides testing other culture methods, the existing oyster strings have been cleaned by scratching the fouling organisms off with a knife. However, this cleaning results in the loss of oysters due to damage of the shells. The young oysters which can be taken off alive are kept in nets suspended between the racks and will be used to continue the culture. From these oysters the approximate age is known so that the time needed to grow up to a commercial size can be followed now.

Maintenance of the culture consists of checking the racks, removal of seaweed and other accumulated matter on and between the oyster strings, removal of sedimentation underneath the strings and between the racks, mortality check of the oysters and building of new racks. During last months some problems became more obvious :

- The untreated mangrove wood used to build the racks appeared to be attacked by insects and sea water. Some of the poles collapsed and had to be replaced. From January 1987 onwards more resistant mangrove wood is used which however is more expensive. Besides, special treatment of the wooden poles should be tested!

- The nylon strings used to hang the oysters are getting brittle, probably due to salt and sun effects. Due to the weight of the oysters, many strings are breaking. A lot of manpower is used now to replace the strings were needed. Besides, other rope material to hang the oysters and culturing oysters in suspended nets should be tested out.

- The submerged culture, followed to compare the growth of these oysters with the ones on the racks, had to be started again as the drum of the former one disappeared during heavy storms, beginning of this year.

- The "wave-breaker" built to prevent too much sedimentation around the racks and under the oyster strings collapsed also, and had to be replaced.

* Laboratory Cultures
Cultures of oysters are tested in the laboratory to study the different larval stages. However, the cultures had to be started over several times to find out under which laboratory conditions larvae can be kept alive upto settlement stage. The larval stages are most sensitive to environmental conditions, as temperature, salinity, water movement and aeration. Up to now, cultures were spoiled by unforseen circumstances : aeration pumps broke down, inoculation of Artemia cysts (wet lab. is located besides Artemia lab), sudden death of the total culture probably due to an infection... New cultures have been started.

* Scientific Reports

- Weston, J. - Tropical oyster culture
  Concerning elaboration of the pilot culture, with social, commercial and scientifc aspects.

- Ruwa, R.K. - Growth of the oyster
  Describing the settlement and growth of the oyster spat

- Abubaker, L. - Biochemical levels in the edible oyster
  Including the study of nutritive elements.

3.2. Plankton Research

3.2.1. Phytoplankton

Study of the primary production are continued every two weeks in Tudor and in Gazi Creek. Chlorophyll measurements are done as well during the same samplings so as to get information on the biomass of the phytoplankton.
These data for a whole year cycle will be compiled by computer to study the evolution of the primary productivity and phytoplankton biomass in function of tidal effects, seasonal influences and

possible input of nutrients by sewage as in Tudor Creek.

* Scientific Report

- De Souza, M. - Biomass and primary productivity measurements at Tudor Creek and Gazi Creeks
  An overview of data for primary productivity during the last six months

3.2.2. Zooplankton

Composition and abundance of near-surface zooplankton is studied on weekly sampling in Tudor Creek at low and hight tide. Study of abundance and distribution of the different species in a specific area and season are done by sampling at different stations along Tudor Creek.

* Scientific Reports

- Okemwa, E. - Zooplankton study in Tudor Creek and Port Reitz
  Including a summary of the ongoing research work

- Okemwa, E. - Analysis of six 24-h series of zooplankton sampling across a tropical creek, the Port Reitz, Mombasa-Kenya.
  Publication submitted to "Marine Biology" Journal

- Kimaro, M. - Marine Zooplankton Studies in Tudor Creek
  Including an overview of the data obtained upto now for the different seasons.

- Kimaro, M. - Abstract of M.Sc. thesis submitted at Nairobi University, at the beginning of this year.

3.3. Chemical Research

Distribution of nutrients in Tudor Creek (ammonia, nitrate, nitrite, phosphate, silicium, POC), salinity and dissolved oxygen are followed at low and high tide every two weeks on water samples and in bottom sediments. These data will be compared with analysis of samples from Port Reitz and Kilindini Estuary as well as with data obtained from Gazi, Bamburi and Malindi.

* Scientific Reports

- Kazungu, J. - Seasonal fluctuation of Nitrate-Nitrogen concentration in Tudor Estuary, Mombasa
  Publication introduced to Kenyan Journal of Science & Technology
- Kazungu, J., Dehairs, F., Goyens, L. - Nutrients distribution patterns in Tudor Estuary during rainy season
  Publication introduced to Kenyan Journal of Science and Technology

- Booker, J. - Analysis of seawater and sediments at Gazi, Bamburi and Malindi to determine their chemical

composition
Summary of research work started in January '87

24h-cycles in Tudor Creek are carried out at spring and neap tide on station 1 (mouth of Tudor Creek) and station 5 (beginning of the creek) during these rainy season. Once the samples are studied, the biological and chemical data will be compiled and described (see also first quaterly report 3.2).

3.4. Coral Reef Research

Since a few years the coral reefs show an obvious degradation. Fundamental scientific approaches have to be introduced for an elaboration of Management of Coastal areas. The research work is focused for a few months on the influence of sea urchins on the coral reef.

* Scientific Reports

- Muthiga, N. & McClanahan, T. - Sea urchin competition study
  Including a summary of the ongoing research work

- Mc Clanahan, T. & Muthiga, N. - Predation patterns on a sea urchin (*Echinometra mathaei*) on Kenyan Coral Reefs
  Publication submitted to Marine Biology

3.5. Mangrove Ecology

Research on different aspects of Mangrove systems in order to collect scientific data needed for the knowledge of the evolution of the ecosystems, is carried on (see also 3.11). Such fundamental research data will form a part of the basis for an elaboration of Management programs.

* Scientific Report

- Ruwa, R.K. - Macrofaunal composition and zonation on sandy beaches at Gazi, Kanamai and Malindi Bay
  Publication introduced to Kenyan Journal of Science and Technology

3.6. Prawns Research

Data for a whole year cycle are compiled for relative abundance, post larval recruitment, growth rates and reproductive cycle of *Penaeus monodon* in Tudor Creek. Results of this study will be described now for a M.Sc. thesis at the University of Nairobi.

* Scientific Report

- Wakwabi, E.O. - Penaeid prawn population in Tudor Creek.

Including a short overview of the data

3.7. Algae Research

Studies on identification, zonation, occurrence and distribution of Marine Algae are carried on. Data were obtained to follow the variations of the intertidal vegetation in relation to season, tidal effect, salinity, substrate and temperature.
Mr. Mwaura has been introduced to the fieldwork, laboratory work and systematics of Marine Algae of the Kenyan Coast. An elaboration of his own research topic will be done with Dr. Coppejans - University of Ghent, during the next months.

* Scientific Reports

- Wamukoya, G. - Seasonal changes in Marine flora along the Kenyan Coast

- Wamukoya, G. - Marine Algae from East African Coast
  Paper written for marine field course of Kenyatta University, Nairobi
  Including classification, uses, mariculture and preservation of Marine Algae

3.8. Fish Research

After their stay for training in the Laboratory of Biochemistry and General Zoology at the University of Antwerp - Prof. Decleir, Mrs. Okoth and Mr. Omolo elaborated a research program on fish physiology. This program has been discussed with Prof. Decleir during his visit at KMFRI, Mombasa in June 1987, and will be started from July 1987 onwards.

* Scientific Reports

- Omolo, S. & Okoth, B. - The physiological respiratory adaptation of <u>Oreochromis niloticus</u> L.
  Concerning the research work done during their stay at the University of Antwerp.

- Oduor, P. - Improved utilization of the Nile Perch
  Overall changes in total volatile bases, acid value (FFA) and organoleptic assessment of Nile Perch stored in ice and at ambient temperature.

3.9. Currents Research

Studies of water movement in Tudor inlet is done to increase the knowledge of the different currents, and to relate these data with distribution of marine organisms, turbidity and the structure of physico - chemical gradients.

* Scientific Report

- Mutua, M. - Current measurements in Tudor Inlet including a first survey in this research field .

3.10. Documentation Centre and Computer Section

A feasibility study for the development of a regional documentation centre and data - bank for the West Indian Ocean Region has been worked out by Mr. Onyango and Mr. Pissiersens during their UNESCO-mission. A proposal for the development of such a computerised network will be elaborated now.
A short term fellowship was offered to Mrs. Mwobobia, Librarian at KMFRI, for a training in computerisation of the Documentation Centre, at the University of Limburg (Belgium) - Prof. Dr. Egghe (April - August 1987).
This training course is designed to provide the fundamental skills necessary for effective use of online information systems.

* Scientific Reports

- Onyango, H. & Pissierssens, P. - Progress report of the KMFRI - KBP Computer Section

- Mwobobia, J. - Education and training for online searching and documentation.
Including the principal objectives of the course.

3.11. Management of Marine Biotopes

During the course of fundamental research work along the Kenyan Coast, it has been shown that Mangrove systems and coral Reefs are in drastic degradation. A scientific approach of these biotopes is needed as a basis for development of management strategies and to ensure intelligent decisions.
More contacts will be elaborated with Wildlife Organisations and with other Institutes in the East African Region to develop a research program on a regional basis, especially concerning Mangroves and Coral Reefs.

* Scientific Reports

- McClanahan, T. & Muthiga, N. - Kenya's coastal fisheries, are they under or overexploited?

- Ruwa, R.K. - Changes in patterns of faunal distribution in Mangrove ecosystems at the Kenya coast, due to natural and unnatural causes.

4. FELLOWSHIPS OBTAINED WITHIN THE FRAMEWORK OF THE KBP

4.1. Short Term Fellowships

* Mrs. Okoth and Mr. Omolo - Ecophysiology
  University of Antwerp - Prof. Dr. Decleir
  May '86 - March '87

* Mrs. Mwobobia - Library and Documentation Sciences
  University of Limburg - Prof. Dr. Egghe
  April - August 1987

* Mrs. Okoth and Mr. Radull - Artemia Training Course
  University of Ghent - Dr. Sorgeloos
  August - September 1987

4.2. Long Term Fellowships

* Mr. Onyango and Mr. Rasowo - Post Graduate Course FAME
  Free University of Brussels - Prof. Dr. Polk
  Academic Year 1987-1988 and 1988-1989

July , 1987

Martens

Dr. E. Martens
Assistant-Director KBP

PROGRAM OF THE UNEP EXPERT MISSION - APRIL/MAY 1987

Prof. Polk visited the different Universities and Institutes on Marine Sciences in the following countries :

DATE	DAY	DESTINATION	DEP	ARR
22/4	WED	NAIROBI	07.05	
		- MAPUTO (Mocambique)		12.55
28/4	TUE	MAPUTO - DAR ES SALAAM (Mocambique - Tanzania)	10.30	15.45
03/5	SUN	DAR ES SALAAM - MOMBASA (Tanzania - Kenya)	16.00	17.40
06/5	WED	MOMBASA - NAIROBI	11.30	12.20
06/5	WED	NAIROBI - MOGADISHU (Kenya - Somalia)	13.25	15.00
10/5	SUN	MOGADISHU - NAIROBI (Somalia - Kenya)	17.45	19.15
11/5	MON	NAIROBI - BRUSSELS		
20/5	WED	BRUSSELS - NAIROBI		
21/5	THU	NAIROBI - MAHE (Kenya - Seychelles)	11.00	15.00
24/5	SUN	MAHE - PORT LOUIS (Seychelles - Mauritius)	13.30	16.00
28/5	THU	PORT LOUIS - ST DENIS (Mauritius - Reunion)	08.10	08.50
31/5	SUN	ST DENIS - ANTANANARIVE (Reunion - Madagascar)	18.00	18.25
04/6	THU	ANTANANARIVE - MORONI (Madagascar - Comores)	13.55	15.25
11/6	MON	MORONI - NAIROBI	17.15	19.15
13/6	WED	NAIROBI - ROME	01.35	07.30

W O R K P L A N

SAMPLING SCHEDULE FOR APRIL 1987

DATE	TIDE	AREA	RESEARCH OFFICER	TRANSPORT	ACTIVITY
Wed 1	LT 11.43	Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
	HT 18.07	Mackenzie Pt.	Mwaura	-	Algae
		Kanamai	MacClanahan	car	Coral Reef
Thu 2	LT 12.11	Gazi	Ruwa/De Souza/Juma/ Mwaura	car	Oysters/Prim.prod. Sedim.Anal./Algae
	HT 18.34	Tudor	Kilonzo	canoe	Prim.Prod.
		Kilindini	Kazungu	canoe	Chemical Anal.
Fri 3	LT 12.38	Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
		Tiwi	Mwaura	car	Algae
Mon 6	LT 14.08	Tudor	Okemwa	canoe	Plankton 5 Stations
	HT 8.29	Diani	Mwaura	car	Algae
Tue 7	LT 15.57 NP	Tudor	De Souza	canoe	Prim.Prod.3 Stations HW
	HT 10.10				
Wed 8	LT 7.10	Tudor	Okemwa	Maumba	Vertical Plankt.Coll
	HT 13.38	Tudor	Mutua/Turi	canoe	Captive Eddies
Thu 9	LT 8.09	Kilindini	Kazungu	canoe	Chemical Anal.
	HT 14.25				
Fri 10	LT 8.43	Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
	HT 14.54				
Mon 13	LT 9.57	Tudor	Kazungu	canoe	Chemical Anal.
	HT 16.17	Mkomani	Mwaura	-	Algae
		Kanamai	Muthiga/Nzau	car	Coral Reef
Tue 14	LT 10.24	Gazi	Ruwa/De Souza	car	Oysters/Prim.Prod.
	HT 16.45	Tudor	Wakwabi	canoe	Prawns Study
		Reef Hotel	Mwaura	car	Algae
Wed 15	LT 10.52 SP	Tudor	Okemwa	canoe	Plankton 5 Stations
	HT 17.13	Old Nyali Bridge	Mwaura	car	Algae
Thu 16	LT 11.23	Gazi	Ruwa	car	Oysters
	HT 17.44	Tudor	Mutua/Turi	canoe	Captive Eddies
		Port Reitz	Mwaura	car	Algae
Fri 17	LT 11.56	Gazi	Ruwa	car	Oysters
	HT 18.17	Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT

DATE	TIDE		AREA	RESEARCH OFFICER	TRANSPORT	ACTIVITY
Mon 20	LT 13.58		Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
	HT 8.12		Malindi	Artemia/Oceanogr.	car	Artemia/Mangrove Ecol
Tue 21	LT 15.18		Tudor	Mutua/Turi	canoe	Current Studies
	HT 9.38		Malindi	Artemia/Oceanogr.	car	Artemia/Mangrove Ecol
Wed 22	LT 17.50	NP	Tudor	De Souza	canoe	Prim.Prod. Engl.Pt.
	HT 11.54		Malindi	Artemia/Oceanogr.	car	Artemia/Mangrove Ecol.
Thu 23	LT 7.02		Malindi	Artemia/Oceanogr.	car	Artemia/Mangrove Ecol.
	HT 13.26					
Fri 24	LT 7.58		Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
Mon 27	LT 9.48		Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
	HT 16.13		Tudor	Wakwabi	canoe	Prawns Study
			Kanamai	Muthiga/Nzau	car	Coral Reef
Tue 28	LT 10.17	SP	Gazi	Ruwa	car	Oysters
	HT 16.44		Tudor	De Souza	canoe	Prim.Prod. 3 Stations LW
			Fort Jezus	Mwaura	car	Algae
			Tudor	Kazungu	canoe	Chemical Anal.LT-HT
Wed 29	LT 10.47		Tudor	Mutua/Turi	canoe	Current Studies
	HT 17.12		Gazi	Ruwa	car	Oysters
Thu 30	LT 11.16		Tudor	Okemwa	canoe	Plankton Engl.Pt. LT HT
	HT 17.37					

Meeting in Library 10.00 a.m.

WORKPLAN : SAMPLING SCHEDULE FOR MAY 1987

DATE	TIDE	AREA	RES.OFFICER	TRANSPORT	ACTIVITY
Mon 4	LT 13.19	Tiwi	Mwaura	car	Algae
	HT 7.30	English Pt.	Okemwa	canoe	Plankton LT-HT
Tue 5	LT 14.04	Kilindini	Kazungu	canoe/car	Chem. Anal. LT-HT
	HT 8.16	Diani/Gazi	Mwaura/Revis	car	Algae/Plankton
		Tudor	Mutua/Turi	canoe	Currents & Plume
Wed 6	LT 15.22	Kanamai	Muthiga/Nzau	car	Coralreef study
	HT 9.34	Tudor	Kazungu	canoe	Chem.Anal. LT
		Tudor	Okemwa/Revis	canoe	Plankton 5 station 200 µm& 335 µm net
		Mackenzie Pt.	Mwaura	-	Algae
Thu 7	LT 17.34 NP HT 11.54	Tudor	Okemwa/Revis/ Kazungu	2 canoes	24-h cycle st.1&5
Fri 8	LT 6.42	Tudor	Okemwa/Revis/ Kazungu	2 canoes	24-h cycle st.1&5
	HT 13.09				
Mon 11	LT 8.44	Mkomani	Mwaura	car	Algae
	HT 15.07	Tudor	Okemwa/Revis	car-Maumba	Vertical Plankton LT-HT collection
Tue 12	LT 9.17	Tudor	Kazungu	canoe	Chem. Anal. LT
	HT 15.41	Tudor	Wakwabi	canoe	Prawns Research
		Gazi	Ruwa/De Souza/ Revis	car	Oysters/Prim.Prod. Plankton
Wed 13	LT 9.50	Kanamai	Muthiga/Nzau	car	Coralreef study
	HT 16.14	Tudor	Okemwa/Revis/ Kazungu	2 canoes	24-h cycle st.1&5
		Reef Hotel	Mwaura	car	Algae
Thu 14	LT 10.26 SP	Tudor	Okemwa/Revis/ Kazungu	2 canoes	24-h cycle st.1&5
	HT 16.49	OldNyali Bridge	Mwaura	car	Algae
Fri 15	LT 11.02	Tudor	Okemwa/Revis	canoe	Plankton 5 st.seri
	HT 17.27	Tudor	Mutua/Turi	canoe	Currents & Plume
		Gazi	Ruwa/Mwaura	car	Oysters/Algae

Mon 18	LT 13.13	KMFRI	Mwaura	-	Algae
	HT 7.27	English Pt.	Okemwa	canoe	Plankton LT - HT
		Gazi	Revis	car	Plankton
Tue 19	LT 14.13	Tudor	Kazungu	canoe	Chem. Anal. LT
	HT 8.27	Rabar rivers	Kazungu	car	" "
		Tudor/Engl.Pt.	De Souza	canoe	Prim. Prod. HT
		Fort Jesus	Mwaura	car	Algae
Wed 20	LT 15.42	Tudor	Okemwa/Revis	car/maumba	Vert.Plankton coll. LT-HT
	HT 9.48	Malindi/Watamu	Artemia/Ocean	car	Mangrove Ecolog
Thu 21	LT 17.29	Malindi	Artemia/Ocean	car	Mangrove Ecology
	NP	Tudor	Mutua/Turi	canoe	Current divergence
	HT 11.19	Kanamai	Muthiga/Nzau	car	Coralreef research
Fri 22	LT 6.07	Tudor	Okemwa/Revis	canoe	Plankton 5 st.seri
	HT 12.36				LT - HT

Mon 25	LT 8.40	Port Reitz	Mwaura	car	Algae
	HT 15.08	English Pt.	Okemwa	canoe	Plankton LT-HT
Tue 26	LT 9.18	Tudor	Kazungu	canoe	Chem. anal. LT-HT
	HT 15.45	Gazi	Ruwa/Revis/ De Souza	car	24-h cycle Oysters
					Plankton/Prim.Prod
Wed 27	LT 9.52	Kanamai	Muthiga/Nzau	car	Coralreef study
	SP	Gazi	Revis/Ruwa	car	24-h cycle Oysters
	HT 16.17				Plankton
		Tudor	Wakwabi	canoe	Prawns research
Thu 28	LT 10.26	Tudor	Mutua/Turi	canoe	Current divergence
	HT 16.47	Tudor	De Souza	canoe	Prim.Prod.3st.seri L.W.
Fri 29	LT 10.58	Meeting Library 10.00 a.m.			
	HT 17.16				

WORKPLAN : SAMPLING SCHEDULE FOR JUNE 1987

DATE	TIDE	AREA	RES.OFFICER	TRANSPORT	ACTIVITY
Tue 2	HT 7.23 LT 13.13	Tiwi/Gazi	Mwaura/Wamuko ya/Ruwa/Omolo	car	Algae Research Oysters/Fish respi ration fysiology
		English Pt.	Okemwa	canoe	Plankton LT-HT
Wed 3	HT 8.09 LT 13.58	Diani/Gazi	Mwaura/Wamuko ya/Ruwa/De Souza	car	Algae/Fish resp. oysters/Prim.Prod. LT-HT
		Kilindini Tudor	Kazungu Mutua/Turi	canoe/car canoe	Chem. analysis Currents study
Thu 4	HT 9.07 LT 14.57	McKenzie Pt. Tudor	Mwaura/Wamukoya Okemwa/Revis	- car/2canoe	Algae Research 24-h cycle St1&5
Fri 5	HT 10.24 NP	Tudor	Okemwa/Revis	car/2canoe	24-h cycle St1&5
	LT 16.19	KMFRI	Omolo	-	Fish resp.fysiol.
Sat 6	HT 11.43 LT 17.50	Kanamai	Muthiga/Nzau	car	Coral reef study
Mon 8	HT 13.35 LT 7.00	Malindi English Pt.	Martens Okemwa	car canoe	Material Fish.Dep. Plankton LT-HT
Tue 9	HT 14.22 LT 7.52	Tudor Kanamai	Kazungu Mwaura/Wamuko	canoe car	Chem. analysis Algae
Wed 10	HT 15.07 LT 8.40	Mkomani Nyali Bridge	Mwaura/Wamukoya Omolo	- canoe	Algae Research Fish resp.fysiolo gy LT-HT
		English Pt.	De Souza	canoe	Prim. Prod. LT
Thu 11	HT 15.52 LT 9.25	Tudor Reef Hotel Kanamai	Wakwabi Mwaura/Wamuko Muthiga/Nzau	canoe car car	Prawns Research Algae Research Coral Reef Study
Fri 12	HT 16.37 SP	Old Nyali Bridge	Mwaura/Wamuko	car	Algae Research
	LT 10.09	Gazi	Ruwa/De Souza	car	Oysters/Prim.Prod. LT-HT
		Tudor	Okemwa	canoe	Plankton 5st.serie 200 & 335um net
		Tudor	Mutua/Turi	canoe	Currents study

Mon 15	HT 6.41 LT 12.25	English Pt. KMFRI	Okemwa Omolo	canoe canoe	Plankton LT-HT Fish resp.fysiol. HT-LT
Tue 16	HT 7.30	Gazi	Mwaura/Wamuko ya/Ruwa/Omolo	car	Algae Research/ Oysters/Fish resp. fysiol. HT-LT
Wed 17	HT 8.25 LT 14.15	Fort Jesus English Pt.	Mwaura/Wamuko De Souza	car canoe	Algae Research Prim. Prod. HT
Thu 18	HT 9.27	Tudor	De Souza	canoe	Prim.Prod.3 st. HW
Fri 19	HT 10.34 NP	Port Reitz	Mwaura/Wamuko ya/Omolo	car	Algae Research Fish resp. fysiol.
	LT 16.45	Tudor	Okemwa	canoe	Plankton 5st.serie 200-335 um net
		Tudor Kanamai	Mutua/Turi Muthiga/Nzau	canoe car	Currents study Coral reef study
Mon 22	HT 13.51 LT 7.16	English Pt. Nyali Bridge	Okemwa Omolo	canoe canoe	Plankton LT-HT Fish resp.fysiol. LT-HT
Tue 23	HT 14.40	Malindi	Artemia/Ocean	car	Artemia/Mangrove Ecology
	LT 8.11	Tudor	Kazungu	canoe	Chem.analysis
Wed 24	HT 15.22 LT 8.56	Malindi McKenzie Pt.	Artemia/Ocean Omolo	car canoe	Artemia/Mangrove Fish resp. fysiol. HT-LT
		Tudor	Mutua/Turi	canoe	Currents study
Thu 25	HT 15.59 LT 9.36	Malindi Tudor Fort Jesus	Artemia/Ocean De Souza Omolo	car canoe canoe	Artemia/Mangrov Prim.Prod. 3 st.LW Fish resp.fysiol. LT-HT
Fri 26	HT 16.33 SP	Tudor	Wakwabi	canoe	Prawns Research
	LT 10.12	Gazi English Pt. Kanamai	Ruwa Okmewa Muthiga/Nzau	car canoe car	Oysters Plankton LT-HT Coral reef stud-
Mon 29	HT 6.01 LT 11.51	English Pt. Port Reitz Meeting Library	Okemwa Omolo 9.00 a.m.	canoe car	Plankton LT-HT Fish resp.fysiol.
Tue 30	HT 6.35	Gazi	Ruwa/Omolo	car	Oysters/Fish resp

1. OYSTER CULTURE

1.1 TROPICAL OYSTER CULTURE

John W. Weston

Introduction

Bivalve fisheries in general are good business, both from an economic standpoint and from the food issue standpoint. Oysters so raised can help to supplement basic research, in the varying fields of science, food for commercial use as well as public and private sectors, and for education. In the tropics, as in many other areas, oyster cultures have the potential of an ever-renewable food resource. The following is an account of the information gathered about the oyster project at Gazi, founded by the Kenyan-Belgium Project in Marine Ecology at K.M.F.R.I., Mombasa - Kenya, under the direction of Prof. Ph. Polk and Dr. E. Martens.

The information cited is in reference to appropriate technology for the villages of the coast. The information covers the reasoning behind of the oyster culture project, project under construction and maintenance, construction costs, and finally a look at some questions on the ecology and biology of the oyster in regards to oyster farming.

1. Fishery Development

There are several factors pointing to what could be termed an "open field" for the development of oyster fisheries on the Kenyan coast. There is already a market for the oysters in Kenya due to the tourist trade. Development of a fishery here would involve intensive unskilled labour, and because there oysters spawn year round (with peaks during the rainy seasons), large numbers of oysters may be cultured year round. Oysters also provide protein that is comparable to that of animal protein found in red meat and eggs. According to Abubaker (personal communication, 1986), the protein content of Crassostrea cucullata is above that of local beef and two other common edible oysters; C. gaser and C. gigas, while still comparing well with the protein content found in the local eggs and that of C. virginica (cf. Table 1. following). There is also an extremely high primary productivity in the mangrove systems of the Kenyan coast; Oysters make excellent use of it:

> The primary production in the watermasses is expected to be up to 750 mg/m (sqd)/day. The mangrove areas are losing, from the watermasses alone, more than 100,000 ton(s) of primary production a year.
>
> Oysters, which are filter feeders (are) converting up to 20% of (this) primary production, can produce 20,000 ton (s) of oyster per year, or 20 ton(s) a day. Oyster cultures are using a tri-dimentional biotope by culturing oysters on racks; 1,000 oysters per meter (sqd) can be cultured: 10,000,000 a hectare. (Polk, Martens, Personal communication, 1986)

1.1 Pollution

Fisheries in the Northern Hemisphere are facing problems with industrial pollution and sewage wastes. There are several areas of the Kenyan coast that are free of the kinds of pollution problems faced by fisheries in the Northern Hemisphere. It is essential that an oyster fishery be located in high quality water because of ".... the danger of transmitting diseases in products which are likely to be eaten without cooking." (Glude, 1976)

1.2 Market and Size

Currently, Kenyan oysters are harvested in the same way as are many seafood products: Local populations from the villages harvest oysters of marketable size from the mangroves and sell them to restaurants or a buyer for a restaurant. It has been found through observation, that these oysters (*Crassostrea cucullata*) often do not grow to a real appreciable size for market (approx. 4 cm.), due to their settlement patterns. Spat settlement is highly concentrated, giving rise to a high degree of competition for space, and little room for growth. Most of the oysters are small, less than 3 cm, and are quite distorted in shape.

2. Site Selection Indicators

Since harvests are already made from the dense oyster populations in mangrove areas, it follows (pragmatically), that a fishery would do well in similar area. As mentioned above, the project site must be free from contaminants and pollutants. A survey of the area should provide the information concerning the distances from possible sources of pollution, and the direction from which the pollution is flowing. In addition, any oysters produced for consumption through the market as a regular food source will be sampled by the health officials, as is already done for the restaurants buying oysters. For the local populations, this is an invaluable resource.

3. Construction/Materials

Materials for the fishery at Gazi are all indigenous to the site except two: Nylon string and marine cement; these items are available locally. Materials for the racks are mangrove poles and nails. These racks are approximately 2m x 4m x 2m. Of course racks of any manageable size may be constructed, as long as the oysters are hung within the tide range (Fig. 1.). Oysters should be fully covered at high tide and fully exposed at low tide.

3.1 Steps in Rack Construction

Step 1.

The tide range is measured and known, the area for construction is then cleared of debris. Following this, distances are measured for 6 foundation poles (Fig. 2.). Mangrove seedlings are used to mark the distances between foundation poles, and holes are dug at the respective sites.

Step 2.

Mangrove poles of approximately 4 1/2m are brought and cut to specific lenghths. The poles are marked 1/4m before the bottom of the pole (the top end has a "Y" to hold the top of the racks; a natural branch) to show the depth they are to be sunk into the substrate. As the substrate is relatively soft, the poles are sunk by brute force.

Step 3.

Top racks are placed in the "Y"s and supports are then added to the sides and middle so as to form 2 cubes (Fig. 3c.).

Step 4.

Final bars are added to the tops of the racks, parallel to the direction of tidal flow. The number of bars at Gazi ranged from 20 to 23, approximately 12 - 15cm apart; the oysters are strung from these (Fig. 4.). The workers made certain that the bars themselves were straight so that the oysters would not hang too close together.

4. Experimental Float

There is also a miniature "long-line" culture of oysters offshore at Gazi. It consists of PVC pipe frame 1m square, netted and tied to a large plastic drum to provide floatation. Strings of oysters, are attached to the frame (Fig. 5a-b.). This method makes it possible to "..... extend oyster culture into deeper waters or unprotected areas". (Glude, 1976) This is also known as a "submerged culture".

5. Oyster Collection

Oysters are collected using a knife or small panga, basket, and where needed, a canoe. Oysters are dug out from mangrove branches, trunks and air roots. The idea is to cut into the bark so as not to harm the oyster. The cut should not be so deep as to harm the tree. Only oysters of about 3cm size should be taken as it becomes difficult to cement smaller oysters. It was observed that the collectors chose to remove the oysters from the drier portion of the trees in order to facilitate removal.

6. Cementation

Nylon strings and marine cement are used to hang the oysters because both are inorganic and are not likely to break down.

Step 1.

Nylon strings of 1 1/2m are knotted in ten places, starting at one end, spacing the knots 10cm apart.

Step 2.

Oysters are cleaned of wood and dirt in order to provide a good surface for the cement's adherance.

Step 3.

The cement is mixed and ten oyster-cement-oyster sandwiches are made on each string at the knot locations. Oysters are cemented left valve to cement; one must be careful not to get any cement on the right valve of the oyster.
The two valves are told apart by holding the animal such that the larger and more cupped valve is on the bottom (left valve) and the smaller relatively flat valve is on top and "fitting inside" the larger (right valve). (Quale and Smith, 1976). The cement takes about eight hours to dry, by the next day, they should be ready for attachment to the racks.

7. Maintenance

The only maintenance observed thus far consists of: Checking the racks to see that they are firmly implanted into the substrate, mortality checks, and the removal of seaweed and other accumulative matter.

7.1 Racks

One of the racks at Gazi collapsed due to shifts in the substrate. These racks can be stood up again and additional supports at angles can be attached (as was done at Gazi). Additionally, breakers can be constructed perpendicular to the direction of stream flow previous to rack construction once a site has been selected. This will slow the stream velocity somewhat and perhaps prevent the racks from collapsing. These breakers will also prevent too much ".... sedimentation around the racks and under the oyster-strings, especially at spring tides". (Martens; Polk, personal communication, 1986) (Fig. 6.)

7.2 Mortality

Mortality cheks are made to keep track of the health of the culture stock. Sinderman (1976), gives a good list of factors leading to mortalities:

> ..... extremes of physical environmental factors, those caused by disease, those due to starvation, those resulting from spatial competition, those due to metabolic competition, those due to predators .... toxins, and unknown origins.

An unhealthy oyster is easy to detect. Walne (1974), relates that the oyster's adductor muscle, which is firmly attached to the valves, is a prominant feature of the organism. The ligaments' elasticity causes the shell valves to gape apart, a characteristic feature of a sick or dead animal. This can be tested in practice by gently tapping one of the valves of the animal, it should snap shut.

7.2.1. Diseases

The widespread occurence of oyster mortality and its disasterous effect make it important to have scientists in the vacinity to identify causes and develop stratagies for treatment and preventative measures (Glude, 1976). The growing KBC/MARSC project at K.I.M.F.R.I. in Mombasa is currently obtaining a variety of scientists that will aid in this problem. In the meantime, what is feasible, as described by Sinderman (1976) is;

> .... the limitation of the extent of mortalities by environmental manipulation (e.g., cleaning the beds of dead shells, collective removal of possible intermediate or reservoir hosts of pathogens, ...); or stock manipulation (moving oysters to low salinity growing areas, (and) planting at prescribed low densities, ...).

7.2.2. Predators

It is also important to be aware of those animals that can cause extensive damage to an oyster farm. Control usually involves proper site selection, fencing or modified culture methods such as raft, long-line or rack systems. Crabs, starfish, and oyster drills are common macro-predators. Parasites are a problem, much like disease that is still under careful scrutiny by oyster projects throughout the world (Glude, 1976).

In Gazi, because of the structure of the racks, this problem of predation is almost non-existant. Parasites have not yet been found, and the mortality rate so far has been low. There is, however, a particular kind of crab that happens to be a rather resourceful predator. Metapograpsus messor, is described by Ruwa to cut the "...edges of the oyster (valves); this causes the shell to helplessly open up." There are other species that are suspect but this one has been observed in predatory action. A few sacraficial oysters are to be placed in an area where there are numerous suspect species of crabs for predator observation (Ruwa, personal communication, 1986).

7.3. Fouling Organisms

A potential problem that has been noticed, is that oyster shells are attractive to spat of oysters and to the spat of other bivalves as well; especially those shells close to the surface (particularly barnacle larva, cf. section 8.8. and Fig. 7.). Again, these additional organisms can create competition for space, one of the factors behind culturing oysters away from their natural settlement sites; to allow room for growth (cf. section 7.2). It has been observed that on the long-line culture, there is the additional settlement of various algal species, hydroids, and other animals.

7.3.1. Control

According to the Agriculture Conference in Kyoto, Japan (Glude, 1976), some control can be achived by providing shade from direct sunlight, and occasionally removing the rafts and spraying the

culture with a concentrated salt solution, which is then allowed to dry, followed with reemersion.
Experiments in the Palau Islands by the Micronesian Mariculture Demonstration Center show that surrounding the rafts with a net enclosure, followed by stocking the enclosure with herbivorous fishes solved the problem.

7.3.2. Remark

It should be noted that the shade mechanism alone is not very effective. Oyster spat tend to settle in dark places and barnacle spat tend to settle high in the water column, both in light and dark places, as has been observed by Ruwa and Martens (personal communication, 1986). Oyster spat, and unfortunately barnacle spat as well, were collected in the inner portion of coconut halves, covered in cement, suspended in the water on nylon strings. This has also been discussed by Walne (1974), noting that oyster spat tended to settle on dark plates rather than on light colored ones.

8. Spatfall: Continuing the Culture

To continue the project (with some order), it is necessary to have an immediate and continuous supply of oysters that provide stock for the culture. Wild oysters, with continued harvesting for stock, could be soon and readily depleted. Thus we have the collection of spatfall. In an open system such as is operated at Gazi, the system is dependent upon the natural productivity of the area. (cf. section 1.), which for Gazi is not a problem.

8.1. Settlement Patterns

The spat of the oyster tend to settle in dark places during daylight hours, and during nighttime hours, spat settlement is reduced. This is mainly a function of the larvae's eye-spot. This has been recorded by Walne (1974) who describes experiments at Conwy where it was shown repeatedly the mature spat settled in dark places. Ruwa (personal communication, 1986), also found comparatively higher settlement in the underside of coconut shells that were covered in cement. (That figure is the percent difference in settlement for under and uppersides of coconut shells; Martens, personal communication, 1986.).

So far, the current system of spat collection (with the most available data), uses a line of coconut shells (5 or 10 to a line) covered in cement. Martens (personal communication, 1986), explains that they have now found more settlement, and better growth on the bottom 4-5 shells than on the top 4-5 shells of the ten shell lines. Very few *Cirripeda* sp. were found where the oyster spat favored settlement and vice-versa, ie., few oyster spat were found to make settlement on the top surfaces of the shells in the upper portion of the water column, but *Cirripeda* sp. were found to settle in these sites (Fig. 7.).

8.2. Catchment methods and Culture material

There are several other methods of spat catchment currently under testing at Gazi:

1. Coconut shell not covered in marine cement, but rather have oyster shells hanging beneath in the concave portion of the shell (Fig. 8a.).

2. Ceramic roofing tiles, hung concave side down with marine cement on the concave side (Fig. 8b.).

3. Wooden boards hung vertically with a shade plate over them, so as to form a "T", all "interior" sides are covered with marine cement (Fig. 8c.).

4. Frames of mangrove wood or bamboo and coconut strings are built, covered in cement and hung vertically in the water between the oyster strings for protection from sediment. There is also a shade plate over the mechanism. (Fig. 8d.). (Shade is provided by oysters and racks, which is not a "true" mechanism.).

8.3. Spat Removal

Two problems have become evident with the development of these methods: spat removal and over settlement. It has been predicted that the concrete covered coconut shells would be the most problematic, as their size and shape does not allow for easy removal of the spat. The roofing tiles are slightly more accessible.

The remaining two methods (boards and frames), have flat surfaces that will allow the spat to be gently scraped or flaked off. An adjustment of the cementation methods under consideration is also suggested by Walne (1974). A slurry of freshly slaked lime, sand and mud is mixed with water such that it is the consistency of thin oil. Whatever is used for spat settlement is then coated with this mixture, enough to provide a coating 2-3mm thick. This mixture tends to break down over about ten months, sufficient time to allow the spat to grow to suitable size (for attachement to the racks) before dropping off. It also allows the spat to be easily removed by flacking off the mortar beneath the spat.

As noted in the above, spat collection is essential in order to have an immediate and continuous supply of oysters that provide stock for the culture. Wild oysters, with continued harvesting for stock recruitment, could be soon and readily depleted.

8.3.1. Over settlement

Selective pithing of the spat will remove new settlers and the slow growers, leaving ample room for the well developing spat. This method ,though applicable to all of the catchment procedures,is time consuming and tedious when it comes to the high volume of spat that are eventually worked with in most culture systems. Further research is being done on the regulation of spat development.

Kamara (1976), suggests taking advantage of the euryhalinity of the oysters and the stenohalinity of the other organisms (oyster larvae, Cirripeda),for settlement control. This can be achieved by combining the above method up to 2-3mm size and then moving the culture to an area where the salinity is high enough (10-15ppt suggested) to permit juvenile oyster growth but low enough to inhibit the growth of other organisms.

9. Construction Costs/introducing a Food Source

Table 2 shows the approximate cost of constructing one of the larger racks at Gazi.The table does not show the costs of harvesting (labour of collecting,transport,etc.) and other capital investments ,such as import of material that is not indigenous to the area cement,nylon strings), and other miscellaneous factors. Still,it is evident that operational costs, even for a village the size of Gazi (pop.approx.500) is more than reasonable.

Currently, wild oysters fetch little more than -/30 Ksh each.This price brings a gross profit of 600/= ksh or $36.17 U.S per 10,000 oysters (1 rack). A fattened ,well produced oyster will bring a higher price in the market place of approximately 1/= Ksh; increasing the profit margin for the grower to about 7,600/= Ksh or $458.11 U.S. It is already known that local restaurants are more than interested in the idea of buying these cultured oysters.

It is also known that oysters are not looked upon as a favourable food by the local population.No specific reason,when asked ,was given as to why oysters were not eaten; considering crabs,prawns,and now even lobsters are eaten by local populations. One consideration is the fact that it is quite laborious to harvest the food for so little meat,but this argument hardly holds when it is seen how many prawns are needed to fill a plate.For the most part it is a matter of introducing the oyster into the diet as a regular food source and not as a luxury item solely for the tourist.The food value (of.Table 1) of these oysters is too important for a developing nation to by-pass.

10. Oyster Biology/Ecology

As mentioned in section 2, it is thought that an oyster fishery would do well in an area where oysters are already in abundance. Many of the problems involved with culturing oysters may be avoided if careful scrutiniy is made of the natural environment. Now that we have some information from the project and literature, a picture of the oyster's ecology and biology in relation to the fishery becomes slightly clearer.

10.1. Euryhalinity: An Asset to the Grower

Oysters are often seen in environments which at first glance would appear to be uncharacteristic of their normal habitat. These sites are often near-shore rocky cliffs and off-shore waters in bays where one would think the salinity is at 35ppt, but upon sampling and further analysis, the salinity is found to be less than that of seawater. Somewhere close at hand is a source of fresh water.

Fresh water enters the brackish water system in three ways: As seepage through a fresh water lens; as discharge from a river system; and as rain. One of these inputs is bound to be evident where oysters are found; seepage usually combining with one of the other two sources.

The oyster's euryhalinity has been taken advantage of for culture situations: moving a culture to low salinities to inhabit the growth of fouling organisms, or to high salinity off-shore waters for continuous feeding are just two examples. C. cucullata spawns throught the year with peaks during the two rainy seasons (Ruwa, personal communication, 1986). According to Quale and Smith (1976), the best time for eating oysters is after they have spawned; as the branching tubes on either side of the body which formerly held eggs or sperms then become filled with glycogen. It is glycogen that gives the oyster its characteristic flavor. Observance of the salinities and the environment allows the grower to harvest a well fattened, tasty oyster and begin to collect spat fall for the next season.

10.2. Remark

It will be noted that Kamara's suggestion about fouling organism control (cf. section 8.2.1.) appears to conflict with the information given in section 10.1. perhaps the culture should be placed in a low salinity area as follows:

1. Since the oyster C. cucullata is reported to have highest spawing activity during the rainy seasons, it follows that the spat might do quite well in low salinity waters.

2. It is also known that mature spat preferentially settle in dark places as a function of the eyespot, and also settle at a high depth in the water column.

3. Finally, those oysters in mid culture (juveniles) may be placed in low salinity areas to combat fouling organisms,. but placed high enough in the water column without shade to combat the settlement of new spat.

As mentioned in the introduction to this section, many facts have come to light about Crassostrea cucullata since work began at Gazi. There is also some question as to how much more the oysters will grow now that they have been given space free of competition. From observing the size of the wild oysters in both the most densely populated areas and in area that appeared to be less densely populated, the oysters that were less crowded were found to be larger and less distorted in shape (cf. section 7.2.). With C. virginicas, it has been shown that the oyster will follow the contour of a hard substrate, the growth of the shell covering or fitting within the substrate (Quale and Smith, 1976).

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Source	Protein Content Dry Wt.
*C. cucullata	56.08 %
C. virginica	49.00 %
*Eggs	45.36 %
*Beef	18.70 %
C. giagas	10.50 %
C. gaser	9.63 %

Table 1. Dry weights comparing protein content.

(*) Indicates analysis of local materials by Dr. Abubaker, L. at K.M.F.R.I., Mombasa Kenya.

Other weights as listed by Giese, Arthur C., "A New Approach to the Biochemical Composition of the Mollusc Body."
Oceanography and Marine Biology. An Annual Review Vol. 7.
Harold Barnes ed. George Allen and Unwin LTD.

Table 2 Cost of Construction for 1 Rack Holding 10,000 Oysters

Labour	
1 String of oysters (20) finished* @ 3/= Ksh ea., 10,000 oysters...	1,500/= Ksh
Rack Construction Labour Costs Approx.:	120/= Ksh
Total Labour Costs	1,620/= Ksh
*Finished string consists of oysters collected, cemented and hung.	
Material Costs	
Nylon strings for oysters 50m per 20 strings @ 15/= ea. Need 500 strings or 1,250m	375/= Ksh
Nails 175grms 3" Nails 175grms 4"	3/31 Ksh
Cement 50 Kilos, 2 bags @ 83/35 ea.	166/7 Ksh
Wood (mangrove)	220/ Ksh
Material Costs	765/01 Ksh
+ Labour Costs	1,620/= Ksh
Total Costs 1 Rack	2,385/01 Ksh

Dollars U.S. @ 16/59 Ksh to $ U.S.
At this time: $143.76 or less than
1¢ U.S. per oyster, -/24 Ksh per oyster.

Source: Dr. Ngoa, M. K.I.M.F.R.I., Mombasa, Kenya

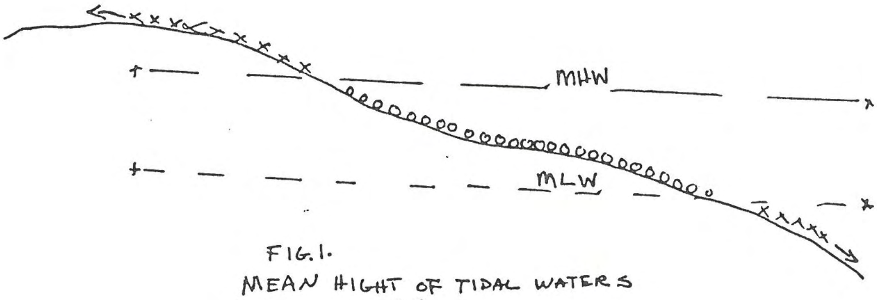


FIG.1.
MEAN HIGHT OF TIDAL WATERS
AND
PLACEMENT OF CULTURES
REPRESENTED BY OOOO

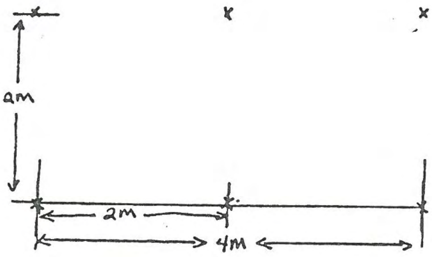
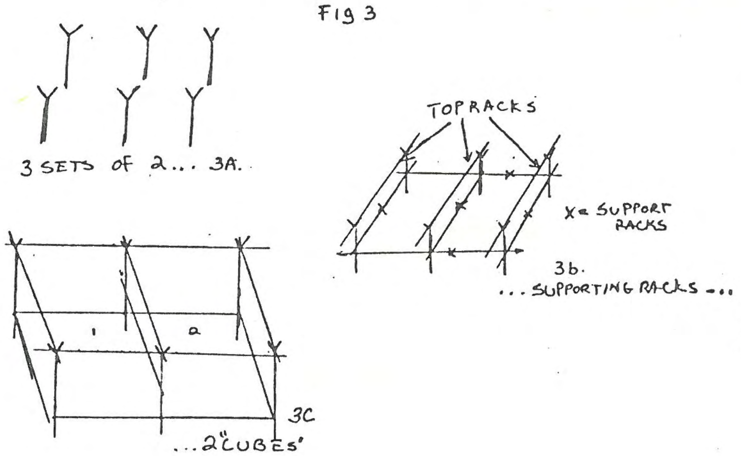


FIG.2.
DISTANCES MEASURED AND MARKED
FOR 6 FOUNDATION POLES.

Fig 3



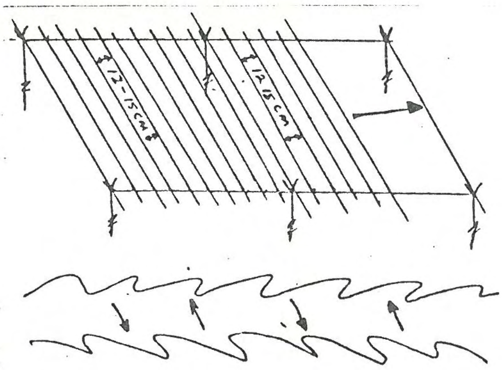


FIG. 4 SHOWING TOP RACKS AND TIDE FLOW.

FIG 5A SIDE VIEW
SUBMERGED CULTURE

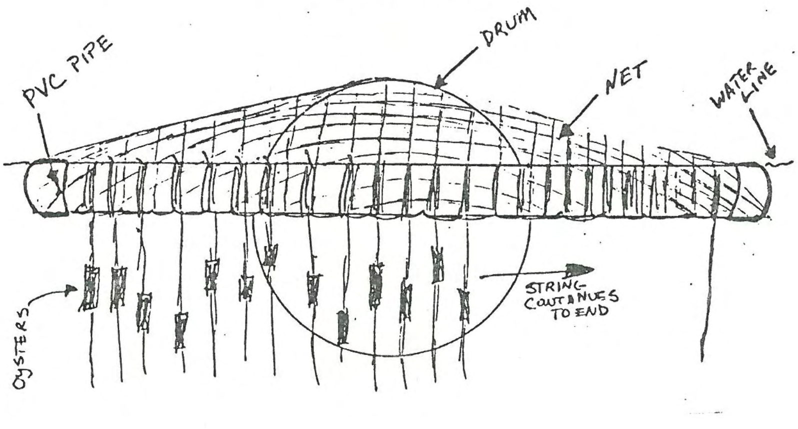


FIG 5b, TOPVIEW
SUBMERGED CULTURE

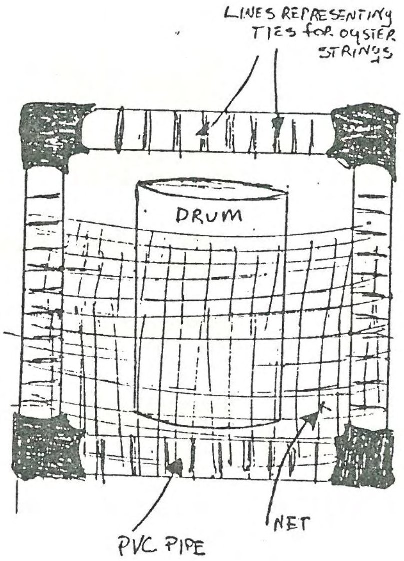
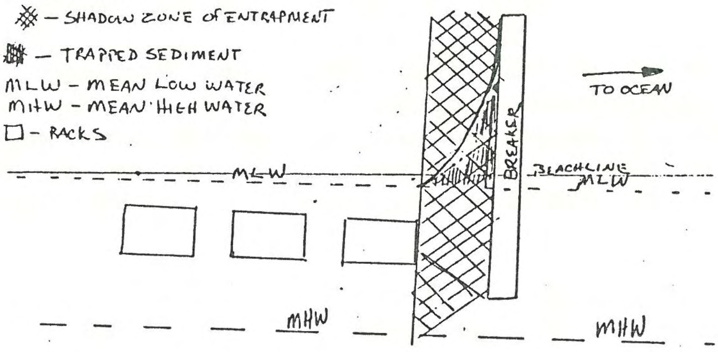


Fig. 6.
BREAKER FOR TRAPPING SEDIMENT

— SHADOW ZONE OF ENTRAPMENT
— TRAPPED SEDIMENT
MLW – MEAN LOW WATER
MHW – MEAN HIGH WATER
☐ – RACKS



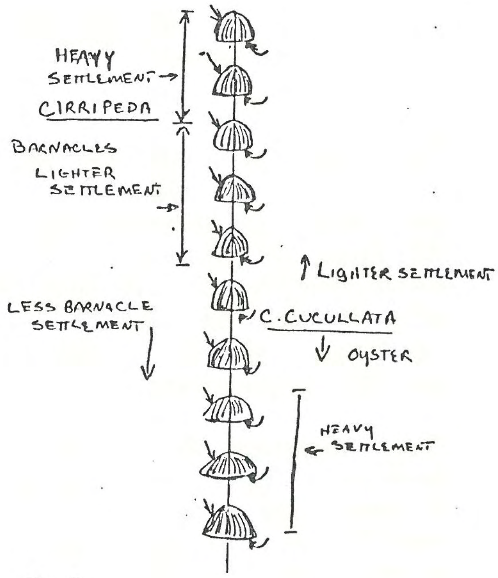
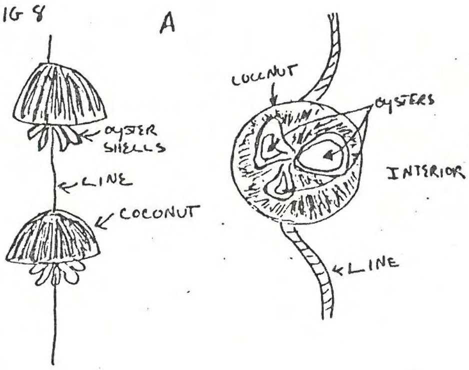
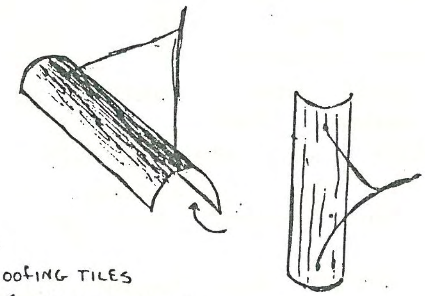


Fig. 7.
SETTLEMENT DISTRIBUTION PATTERN of CIRRIPEDA sp. AND C. CUCULLATA
ARROWS INDICATE SETTLEMENT of OYSTER SPAT
ARROWS INDICATE BARNACLE SETTLEMENT

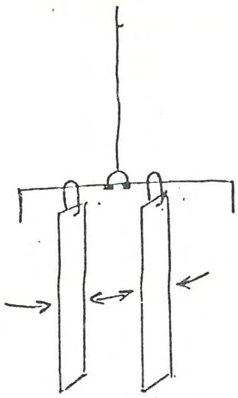
FIG 8 A





8b.
ROOFING TILES
SUSPENDED BY NYLON WIRE.
ARROW INDICATES PREFERRED SETTLING SITE

FIG. 8C.



BOARDS COVERED IN CEMENT
ARROWS INDICATE "INTERIOR" AREAS WHICH ARE SHADED TO PROMOTE SETTLEMENT.

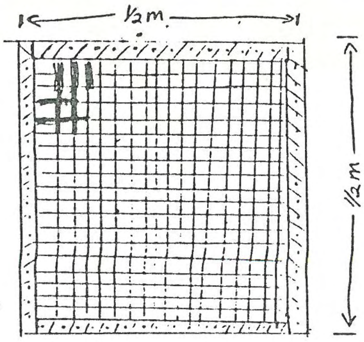


FIG. 8D.
WOOD FRAME OF BAMBOO OR MANGROVE STRUNG WITH LINES OF COCONUT STRING
– SHADED AREAS REPRESENT CEMENT FOR SPAT CATCHMENT. THE FRAME IS HUNG VERTICALLY

1.2. GROWTH OF OYSTERS AT GAZI CREEK

R.K. Ruwa.

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The growth of the edible oyster Crassostrea cucullata Born is being monitored at the Gazi Oyster Culture Pilot Project. This project is within the famework of the Kenya/Belgium Project in Marine Sciences. The measurements started from the time of settlement of the oyster fry on cemented coconut collectors which are placed at various levels above the datum. The change in the maximum shell lengths of the oysters was used to study the growth patterns.

The measurements showed that the growth rate was higher at lower levels than at higher levels. For example it decreased from 3.5mm per month at lower levels (1.1m above datum) to 3.0mm per month at the intermediate level (2.1m above datum) and 2.0mm per month at higher level (2.9m above datum) within April and December 1986.

Interchanging the positions of the oysters such that those that were growing at higher level were transfered to lower levels and vice versa, the following was observed. The oysters transfered from 1.1m to 2.9m showed reduction in growth rates from 3.1mm per month (within April and May 1986) to 2.3mm per month (within June and December 1986). But those transfered from 2.5m to 1.5m above datum showed an increase in growth rate from 1.8mm per month (within April and May) to 2.9mm per month (within June and December 1986). This indeed demonstrated that the oysters grow faster at lower levels of the shore. These growth rates were under the influence of competition for space between barnacles and the oysters and among the oysters themselves.

To reduce the competition for space and find out if growth rate would increase, another investigation was made whereby all barnacles were removed and the oysters thinned out to create space for growth. The rates increased at both higher and lower levels. The growth rate at 2.9m was 2.9mm per month and at 1.3m, 4.4mm per month within April and December 1986.

Oysters grown on a floating raft under fully submerged conditions became fouled by the algae Glacilaria corticata which literally formed bushes by attaching even on the oysters. The latter showed almost no growth.

1.3 A STUDY OF THE BIOCHEMICAL LEVELS IN COMMERCIAL OYSTER, CRASSOSTREA CUCULLATA BORN

L. Abubaker

Oyster meat is regarded in the Western world as first class food of high quality protein, rich in valuable lipids, essential minerals and fat which are all necessary for a balanced diet.

A sample of 20 oysters collected from the rafts at the Gazi oyster culture experimental project in March 1985 was analysed for its food value. The results obtained were compared with C. virginica (Galtsoff, 1964), C. Gigas (A.C. Giese 1969), local beef and chicken eggs.

For the biochemical estimations, the levels (in % dry weight) of protein was determined by the semi-micro Khedahl method (Joslyn, 1970) using 6.25 as the conversion factor. The total carbohydrate (as % glucose) was estimated by the anthrone method (Seifter et al, 1950) while the moisture content was determined by drying at 100°C to constant weight.

In June I started analysing twice a month to find the stage of maximum percentage in the nutrients during the year. The analysis carried out so far shows that seasonal variation in biochemical constitution does exist.

For the water content the highest value (86.9% wet weight) was obtained in August 1986 when the oysters have finished spawning. However, there is a simultaneous decrease in protein and carbohydrate levels. The protein level showed a maxima around July (55% dry weight) and another one in November 1986 (49.4% dry weight). As for the total available carbohydrate, the peak was in October and November 1986 (13.5% and 12% dry weight respectively) when the oysters were fat and filled with creamy meat. Then there was a gradual drop in protein and carbohydrate levels after November and the decrease has continued steadily until my last sampling on 8th January 1987 so I am still following the trend. I have to continue for the next two seasons in order to get concrete conclusions and to compile the data for a whole year cycle.

2. PLANKTON RESEARCH

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2.1. PHYTOPLANKTON RESEARCH

BIOMASS AND PRIMARY PRODUCTIVITY MEASUREMENTS AT TUDOR AND GAZI CREEKS.

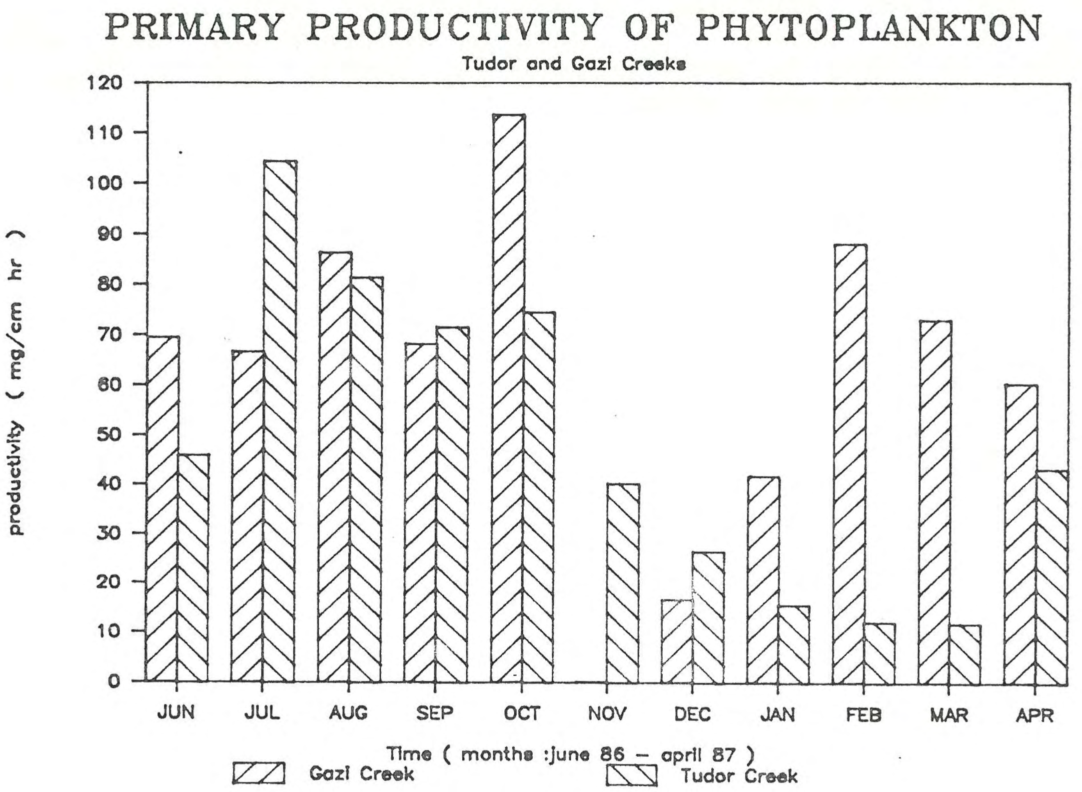
M. Desouza

Primary productivity measurements were taken at Tudor and Gazi Creeks. Tudor Creek was sampled at English Point, and it was found to have an average primary productivity of 60.91 mg $C/1m^3$ /1hr. Gazi creek had an average productivity of 65.11 mg $C/1m^3$ /1hr. Gazi creek thus has a higher productivity than Tudor creek. The highest productivity was noted in the month of July, 104.49 mg C/m^3/hr for Tudor creek and the lowest in December 11.90 mg C/m^3/hr. Gazi creek had the highest productivity in October, 113.54 mg C/m^3/hr and lowest in December of 16.66 mg C/m /hr.

Three sampling stations 1,3,5, were selected from the mouth of the creek upwards for comparisons of their primary productivities. Station 1 had an average of 15.64 mg $C/1m^3$/hr, station 3, 47.32 mg $C/1m^3$/hr, and station 5, 8.93 mg C/m^3/1hr. Thus station 3 was the most productive area in terms of primary productivity.

Chlorophyll 'a' measurements were used as an indication of phytoplankton biomass. Gazi creek had a higher biomass of phytoplankton as indicated by high chlorophyll 'a' values of 18.88 mg/L where - as Tudor creek had a lower biomass of phytoplankton 6.04 mg/L .

Samplings carried out twice a month at each of the creeks, Tidal events are also being compared and further trends are being monitored.



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2.2. ZOOPLANKTON RESEARCH

2.2.1. ZOOPLANKTON STUDY IN TUDOR CREEK AND PORT REITZ

E. Okemwa.

Introduction

Zooplankton are an extremely important link in the food webs of Marine ecosystems.

The Zooplankton group is concentrating on the following studies:

1) Annual cycle of species composition, abundance (biomass), and size distribution of zooplankton at Tudor Creek,

2) 24 -hours zooplankton sampling across, a tropical creek, the port Reitz, Mombasa

Study Areas:

Studies on zooplankton communities have been going on from the following localities:

1. Five fixed stations in Tudor Creek, are sampled twice a month in spring and neap tides respectively.

2. English point has been selected as a representative near shore area (for Tudor Creek) and is being sampled twice weekly.

3. 24-hours cycle experiments in neap and spring tides during rainy and dry seasons respectively at Tudor Creek and Across Port Reitz, Mombasa.

Methods and Equipment

Field sampling

At Port Reitz quantitative near - surface Zooplankton samples were collected from a car ferry using the Clarke - Bumpus high speed sampler having a mouth area of $0.017m^2$. The Clarke - Bumpus was equiped with a net (mesh 180 μm) was used throughout.

Laboratory Methods

Preparation for analysis involved passing the sample through a 42 μm mesh sieve and placing the residue in the petri dishes. The sub-samples was sorted out under a stereo microscope and copepods were put out separately in the petri dishes. Determination of the copepods to species level was carried out by dissecting and drawing the antennae, antennules, mouth parts, thoracopods and furca.
Numerical density was determined from the counts of the total sample or sub - samples.

Results

(a) ZOOPLANKTON

Short-term zooplankton data are drawn from six 24-h series across Likoni Ferry, using Clarke - Bumpus net of 180 um Pore size. Salinities were consistently above 30 parts per thousand at Likoni Ferry. Water temperature varied between 24.0 C and 28.9 C. Fifty-one taxa of zooplankton organisms were recorded in the samples. Total zooplankton abundance averaged 236/m^3. The density of zooplankton was highest during the 24-h series of February during the north-east monsoon season during November to March. Holoplanktonic forms dominated the fauna, averaging 71% of the total plankton; copepods numbered 69% of the total fauna. The most numerous taxa amongst holoplanktonic forms were (in order of abundance) : copepods, chaetognaths and appendicularian. Actual mean abundances of holoplankton were relatively low during the 24-h series taken in South-East monsoon in April, June, August and October. The most numerous amongst meroplanktonic forms were : Molluscan, Fish eggs and Brachyuran zoeae. The total zooplankton for the night-time samples were higher than the day-time ones, but varied from one sample to another.

(b) COPEPODS

Surface copepod samples were taken from car ferry across Port Kilindini (Likoni Ferry- Mombasa) during April, June, August, October, December 1985 and February 1986. These included six 24-h series. Six new record for the Western Indian Ocean are cited. The analysis of relative abundances shows that changes occur among abundant species of copepods: *Corycaeus* spp., *Acrocalanus* spp., *Oithona* spp., *Acartia* spp., *Oncaea* spp., *Macrosetella gracilis*, *Centropages* spp., and *Temora* spp. This study revealed a regular faunal cycle caused by Spring-neap tidal cycle and high-low tidal cycle.

2.2.2. ANALYSIS OF SIX 24-HOURS SERIES OF ZOOPLANKTON SAMPLING ACROSS A TROPICAL CREEK, THE PORT REITZ, MOMBASA, KENYA

E. Okemwa

ABSTRACT

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Short-term zooplankton data are drawn from six 24-h series across Likoni Ferry, using Clarke - Bumpus net of 180 um pore size. Salinities were consistently above 30 parts per thousand at Likoni Ferry. Water temperature varied between 24.0 C and 28.9 C. Fifty-one taxa of zooplankton organisms were recorded in the samples. Total zooplankton abundance averaged 236 /m³. The density of zooplankton was highest during the 24-h series of February during the north-east monsoon season (during November to March). Holoplanktonic forms dominated the fauna, averaging 71% of the total plankton; copepods numbered 69% of the total fauna. The most numerous taxa amongst holoplanktonic forms were (in order of abundance): copepods, chaetognaths and appendicularian. Actual mean abundances of holoplankton were relatively low during the 24-h series taken in South-East monsoon in April, June, August and October. The most numerous amongst meroplanktonic forms were : Molluscan, Fish eggs and Brachyuran zoeae. The total zooplankton for the night-time samples were higher than the day-time ones, but varied from one sample to another.

INTRODUCTION

Marine zooplankton communities have been extensively studied for many years, but literature on tropical East African inshore plankton is lacking. Our knowledge regarding the diel, tidal and seasonal changes in composition and abundance of plankton from the creek waters of Mombasa is mainly due to the work of Reay and Kimaro (1984).

Despite the size, recreational and commercial importance of the creek, both to fisheries and as a Port facility, nothing has been previously published on general zooplankton. Detailed analysis of pelagic copepod species distribution patterns form the basis of a separate forthcoming paper.

In this paper I analyse six 24-h series of zooplanktonic and hydrological collected across a creek of the Port Reitz, Mombasa. By sampling at 2 hours intervals in each 24-h cycle and every after two months for a year the aim is to find out the influence of tidal cycles on the diel fluctuations of the different zooplanton taxa, and the extent of the exchange of zooplankton biomass between the creek and the sea owing to tidal transportation. Knowledge of these subjects is basic to understanding the dynamics of zooplankton populations and communities and their role in the trophic structure of the lagoon ecosystem (UNESCO, 1981).

These observations of inshore plankton and abiotic factors were part of the project undertaken under Kenyan/Belgian Biological Oceanography Project.

STUDY AREA

Mombasa lies 450 km south of the Equator (latitude 4°S, longitude 40°E). Likoni Ferry is the car ferry connecting Mombasa Island with South Coast mainland across the mouth of Port Reitz Creek (Fig.1), which harbours extensive areas of mangrove, as well as open water channels, mud-flats and banks. It would enable mid-channel tows to be made at any time of day or night.

The topography of the East African Coast strip shows clear evidence of pleistocene reef growth and erosion (Caswell, 1953; Thompson, 1956). Two major episodes of reef growth during periods of elevated sea level of which varies along the shore due to uplift and faulting which formed underwater notches in the limestone and deeply cut river valleys which later were covered by the rising sea and have formed sheltered mangrove-lined inlets known locally as creeks (Sikes, 1930; Thompson, 1956; Alexander, 1968).

Generally the year can be divided into two wet seasons (April-June and October-November) and two intervening dry seasons which are dominated by north-easterly winds from December to April, and by South-easterlies from May to November and the precise timing and extent of each season varies considerably from year to year (Grove et al, 1986).

The perennial Rivers Mwachi, Mambone and Cha Simba (Pemba) feed in the top of Port Reitz Creek. Strong tidal currents may occur along breaks in the reef and at the opening of the creek. Sediments of Likoni Ferry are predominantly mud and some parts is coverd by sand.

FIELD AND LABORATORY METHODS

Sampling Procedure

Quantitative near - surface zooplankton samples were collected from a car ferry using the Clarke - Bumpus high speed sampler having a mouth area of 0.017 m^2. The Clarke - Bumpus sampler equiped with a net (Mesh 180 um) was used throughout.

The duration of each tow was 4 min towed at 1.6 m/s which was calculated by suspending the Braystoke current meter alongside the sampler from the car ferry with a 480 hp diesel power engine. After each tow, the condend was removed, the net was thoroughly washed with seawater.
Every catch was preserved in buffered 5% formalin. The volume of water filtered was estimated with flowmeter fixed inside the sampler.

Samples were taken in a 24-h cycle series starting at 08.30 hrs to 06.30 hrs once a month and after every two months for a year starting on 24th April, 1985 to 25th February, 1986. Samples of April, June, August and October 1985 were taken between neap and spring tides, while those of December, 1985 and February, 1986 were taken during neap and spring tides respectively.
Surface water temperature and oxygen were recorded whenever sampling was done. An electronic sampling oxygen meter and

temperature probe (OX1 91) was used.
Salinity was usually recorded with the use of a simple refractometer, but this only recorded to the whole unit of 1%. pH was measured with a pH meter (Orion Research model 231 pH/mv/temp.). SiO_2 was also measured with a quick testing kit (Aquaquant 14410 SILICIUM).

Laboratory Procedures

If a sample contained a noticeable conglomerate of detritus or Phytoplankton, the Zooplankton portion was separated from this material by gentle filtration through 42 um mesh netting. Before estimates of biomass or density were made, all organisms larger than 1 cm, usually hydrozoan medusae were removed. The residue was placed in the petri dishes. The whole samples was observed. Zooplankton identification and counting were effected according to the main taxa. Zooplankton was volumetrically subsampled using a modified stempel pipette. Five subsamples were taken from each tow, the volume generally being 1/10th that of the sample. In some cases samples were so sparse the entire sample was examined. Analyses were made under a sterio microscope. Groupwise analysis of the sub-samples was made and enumerated. The plankton biomass was determined by displacement method.

RESULTS

Hydrological Features

Fluctuations in the Temperature

The maximum sea- surface temperature being 28.9 °C was attained in both December, 1985 and February, 1986 the minimum being 24.0°C during August, 1985 (Fig.2). In the surface-water the range of diurnal variation of temperature for six 24-h series in April, June 1985, August 1985, October 1985, December 1985 and February 1986, was (24.0 - 26.0 °C) 2.0 °C, (25.0 - 27.0 °C) 2.0 °C, (24.4 - 25.3°C) 0.9 °C, (26.3 - 28.0 °C) 1.7 °C, (27.3 - 28.9 °C) 1.6 °C and (26.4 - 28.9 °C) 2.5 °C respectively (fig.2). In all occasions the temperature remained steady from 14.30 hrs to 16.30 hrs. After 16.30 hrs the temperature began to decline with fluctuations following the tide. There was an increase of temperature during low tide which can be attributed to the in-coming estuarine water and high tide the temperature declined due to the in-coming tide with cool water.

Salinity

Maximum and minimum salinities were recorded in February and June respectively. Low salinity reading at 20.30 hrs on 24th April 1985 may have coincided with a heavy rain, while a second decrease occurred on 25th June 1985 at 20.30 hrs was caused by rain also, but the overall the salinity of the water was strikingly stable (Fig.2). The range of salinity at the surface is 6% and the fluctuations correspond to the tidal variations. The surface waters showed the maximum salinity at high tide and slightly low salinity in low tide (Fig.2).

Plankton Volume

Total zooplankton volume was relatively low in the 24-h series of June, 0.05ml/m at 12.30 hrs, but increased from December series (2.5 ml/m) which occurred at 18.30 hrs. The high February plankton volume was mainly attributed to the mysis stage of caridea.

Dissolved Oxygen

The surface oxygen shows a trend similar to that of surface salinity. However, the overall pattern of variation is like that of temperature.
The concentration of oxygen in the surface water varies from 4.2 mg/1 to 7.8 mg/1. The lowest dissolved oxygen concentration was recorded at 08.30 hrs in February in North-East monsoon period while the highest was at 12.30 hrs in June during the South-East monsoon.

There is a general tendency for the oxygen concentration to increase in the surface water with the rise in temperature (Fig.3). This occurred in the afternoon when the solar radiation was high and when the photosynthetic production of oxygen was high. Basically, two different phenomena appear to influence oxygen variations over the six 24-h sampling period: the day-night cycle of the photosynthesis and respiration processes and the movement of water masses with different oxygen content through the sea mouth.

SiO

The highest and lowest values for silicates at the surface were during 25th february, 1986 ($\overline{x}$ = 0.63 mg/1; SD = 0.02) and 28th August, 1985 ($\overline{x}$ = 0.09 mg/1; S.D = 0.06). Most of the measurements during the period of study were fairly stable, except in four other cases in April 1985, June 1985, October 1985,and December 1985 where the values fluctuated between 0.02 mg/1 and 0.65 mg/1 (Fig. 3).

pH

The surface pH ranged between 8.3 and 7.85 (Fig.3). Expressed graphically as a function of time, a straight line pattern emerged, for the most period sampled, completely different from the curves for the other parameters studied.

Tides and Tidal range

The tides in western Indian ocean are Semi-diurnal. According to Brakel (1982) the average tidal ranges at spring tide days and neap tide days are 3.2 m and 1.0 m respectively. Fig. 4-5 show the tidal range during the six different periods of study.

RESULTS

A total of 72 tows was taken during the six 24-h series experiment. Of this number 48 hauls were in April 24/25, June 24/25, August 28/29 and October 30/31, 1985, mostly during the south-east monsoon winds and mid-spring and neap tides. The 24-h tows taken in December 4/5, 1985 and February 25/26, 1986 were taken during north-east monsoon winds and during neap and spring tides respectively.

Total zooplankton

The zooplankton is rich and abundant and over 51 taxa were recorded in the Likoni Ferry (Table 1).
An average of 236 organisms/m^3 was recorded throughout the year but actual abundance varied from time to time during the 24-h cycle.

Copepoda group was the most important constituent of the zooplankton community throughout the 24-h series followed by Calanoida and both followed the zooplankton pattern distribution during the study period (Fig.4 and 5).
Total zooplankton abundance for each tow in the six 24-h series is given in figure 6 in which the Copepoda group was the most important constitutent.

April 24/25
This mid-spring and neap tide showed a very clear difference bbetween day and night samples with an indication of a peak in the early part of the night (Fig.4). This peak coincided with the flooding tide after sunset.
The peaks at 20.30 hrs involved high numbers of copepods and Brachyuran zoeae. The lowest values was during ebb tide from 10.30 hrs to 12.30 hrs.

June 24/25

This mid-spring and neap tide demonstrated a clear difference between day and night samples; the night samples were mostly lower than those of April 24/25. Over the 24-h period, I recorded a cyclic variation with 5 maxima in June series at 04.30 hrs before flood tide (Fig.4).
The two peaks during sunrise and sunset coincided with high tide. In terms of composition, calanoid numbers influenced the rise in abundance. The lowest values during ebb tide from 10.30 hrs to 12.30 hrs was on June 24/25, 1985.

August 28/29
The zooplankton displayed a tri-modal pattern of distribution and average highest densities at 08.30 hrs and 06.30 hrs after flood tide respectively. This series is quite different from the previous ones although it was taken during mid-spring and neap tide. The first peak for the series occurred at 08.30 hrs (sunrise) was caused by Thalia democratica and fish eggs.
Apart from the differences, the nocturnal pattern, with a peak at 22.30 hrs at ebb tide, the minimum for this series was after ebb tide at 14.30 hrs, and 02.30 hrs respectively (Fig.4).

October 30/31
A four-modal pattern of distribution was demonstrated in this series of October (Fig.5). Two conspicuous peaks occurred at 10.30 hrs and 00.30 hrs during ebb tide. The first peak at 10.30 hrs was contributed by copepods and Bivalve larvae, (Fig.5).

December 4/5
This neap tide had more plankton in the night than day, with a peak during mid-night and the other peak at 16.30 hrs, and both

coincided with the ebbing tide respectively (Fig.5). The lowest night value coincided with a high tide. The peaks at 16.30 hrs involved high numbers of copepods and Oikopleura, while the one at 00.30 hrs involved Copepods, Cirripede nauplii and Brachyuran zoeae.

February 25/26
This spring-tide series showed a clear difference between day and night samples with an indication of a bimodal peak in sunset and early part of morning (Fig.5). These peaks coincided with the flooding tide, and were caused by high numbers of calanoids, fish eggs and Oikopleura.
Overall numbers were about twice as high as the previous neap-tide series (December 4/5). The peak at 04.30 hrs appeared with maximum numbers two hours before high tide. The lowest values occurred during ebb tide from 10.30 hrs to 12.30 hrs and from 20.30 hrs t0 02.30 hrs.

Meroplankton and holoplankton forms

Numerical relationships between holoplankton and meroplankton are shown in figure 7 and 8. Holoplankton organisms dominated the fauna, averaging 71% of the total 167/m^3 but ranged from 64% in April 24/25 1985 to 76% in February 25/26 1986. Actual mean abundances of holoplankton were relatively low during the period of south-east monsoon April 24/25, June 24/25, August 28/29 and October 30/31, 1985 (122/m^3) as compared to north-east monsoon in December 4/5, 1985 and February 25/26, 1986 which was double more (268/m^3).

Meroplanktonic organisms formed a considerable portion of the fauna, averaging 29% (68/m^3). Meroplanktonic organism showed a single peak pattern of distribution during the period April 24/25, June 24/25, and August 28/29, 1985 and during ebb tide and night time. In October 30/31 and December 4/5, 1985 the pattern exhibited by meroplanktonic organisms was bi-modal. The first peak occurred during ebb tide and all in the night. In February 25/26, 1986 there was no clear pattern.

A brief description of the composition and temporal trends of the single taxa at Likoni Ferry is given below:

Individual Taxa

The most highly represented species were those typical of neritic plankton : Centropages orsinii, Acrocalanus spp., Clausocalanus spp., Temora turbinata and Paracalanus spp. (Calanoids), Oncaea mediterranea, and Corycaeus sp. (Poecilostomatoids), Oithona spp. (Cyclopoid) and Macrosetella gracilis (Harpacticoid).

Tunicates :

Tunicates were represented only by Appendicularia and Doliolum sp. which appeared more frequently and with highest mean density 557/m^3 and 600/m^3 on the December series during the north-east monsoon and at flood tide.

Chaetognaths :

The numerical importance of Sagitta spp. was very low with a maximum value of 50/m^3 at flood tide during north-east monsoon on the December series.
Figure 9 compares mean totals in six 24-h series and maxima for chaetognaths in December and February.

Cladocera :

Evadne tergestina was found sporadically in all series, but more were found in August series. The highest densities 3/m^3 occurred at ebb tide.

Ostracods :

Pyrocypris and Euconchoecia appeared in all the six 24-h series and mainly in the night. Their maximum density 6/m^3 occurred during ebb tide in June and February series.

Amphipods :

Hyperia and Synopia ultramarina were commonly collected in all the six 24-h series, with maximum numbers 12/m^3 at 18.30 hrs in October series after flood tide.

Ctenophores :

Pleurobrachia sp. was encountered in April series, averaging 0.7% (2/m^3) of all non-copepod fauna caught during ebb tide at 10.30 hrs and 24.30 hrs, and none was captured during flood tide.

Siphonophores :

Pysalia, Diphyes and Lensia were present in all six 24-h series. Collectively they formed in average about 1% of the total non-copepod fauna, and the highest recorded densities was 6/m^3 at 02.30 hrs during ebb tide.

Hydrozoan medusae :

Liriope sp. and Solmundella bitentaculata were recorded at densities up to 24/m^3 during February series.

Polychaete Larval :

Larval polychaetes occurred in the six 24-h sampling cycles. Maximum numbers occurred at 00.30 hrs. The eggs of Nereid were abundant in the samples collected at ebb tide around 00.30 hrs during the February series. Figure 9 compares total polychaete larvae abundance for each series. February and April series are found to have the highest numbers.

Cirripedia :

Nauplius and cyprid larvae of barnacles were in the 24-h cycle of August, October, December and February averaging 7%, 6%, 8% and 3% of the non-copepod fauna respectively. Cirripede larvae (nauplii were clearly prevalent over cypris) were numerous (33 - 38/m^3) at early hours of the morning at the beginning of the flood tide phase and also at ebb tide during the night.

Cryptoniscid :

Cryptoniscid isopod larvae were taken in the 24-h cycle of April, August, October and February.

Amphioxus :

Amphioxus though rare were recorded in the August and October series. They were nocturnal and were found between 20.30 - 00.30 hrs, averaging 0.3% of the non-copepod fauna ($4/m^3$).

Stomatopod :

Larva of Alima type was in the 24-h of June, August and December at 10.30, 14.30 and 22.30 hrs in abundance of 0.25, 3, $1.5/m^3$ respectively.

Cumaceans :

Cumacean spp. were recorded in August and October 24-h series, and only were found between 20.30 - 04.30 hrs with maximum number of $4.5/m^3$ at 00.30 hrs.

Mysids :

Hemisiriella and Anchialina were caught in abundance of $3/m^3$ in the 24-h series of October and December at 18.30 hrs and 22.30 hrs respectively, and in the rest of the 24-h series the catch was scarce.

Scalps :

Scalps and doliolids were observed sporadiaclly in very low numbers in all the six 24-h series and only during flood tides.

Euphausiid :

Euphausiid appeared in all the flood tides of the 24-h series of June, August, October and December 1985. None was caught in the ebb tide and the 24-h series of April and February.

The Diel Cycle for Selected Taxa

Figure 10 gives a summary of the abundance of Molluscan, Fish eggs, Fish larvae, Brachyuran larvae, mysis stage of Penaeidae and mysis stage of Carideae throughout the six 24-h series.
These groups were selected to compare with earliest 24-h series carried from the floating pontoon of the Kenya Marine and Fisheries Research Institute near Likoni Ferry by Reay and Kimaro (1984).
Except for fish eggs and mysis stage of penaeids the highest sample values were obtained at night and this agrees with Reay and Kimaro (1984).
The lowest values in 24-h series of June, except for mysis stage of Caridea occurred between 12.30 - 18.30 hrs and this compares well with the data of Reay and Kimaro (1984) but the rest of the 24-h series showed a very high dis-similarity. It was in the 24-h series of April, June and December, the second half of the night was more productive than the first half.

For the 24-h series of August, October and February the difference between the first and second part of the night was not conspicuous.
Penaeids were found during flood tides in the 24-h series of June, December and February at 08.30, 20.30 and 04.30 hrs respectively mysis stage of Caridae occurred in high numbers after mid-night during ebb tide in the 24-h series of April.
Most Caridae were caught after dusk with numbers reaching a peak two hours after flood tide.
With respect to egg numbers, the 24-h series of August, October 1985 and February 1986 showed peaks around flood tides and troughs around ebb tides. Figure 10 shows that the night-time peak in egg numbers is greater than the day-time peak except for the peak of the series of April which occurred before 08.30 hrs.
Larval densities were more in the night than day time in all the six 24-h series and maxima in most cases occurred at 00.30 hrs (Fig.10).
Figure 11 shows total eggs and fish larvae abundance in all the six 24-h series. Fish eggs were found highest in the series of December 1985 and February 1986, but fish larvae didn't show any great variation.
Decapod larvae (Fig.10 & 11) were very diverse. Even as a group considerable variation was evident, with large numbers being present in April 1985 and low numbers in June 1985 series.
Mysis of Penaeid and Caridea were present in maximum numbers in during the April and June 1985 series and scarce in the rest of the five 24-h series.
Penaeids included Penaeidae and Sergistidae (_Acetes_, _Sergestes_ and _Lucifer_). _Acetes_ and _Lucifer_, all reached maxima in April 1985 (Fig.9). _Lucifer_ had high abundance of 1.8 and 1.5/m^3 at 10.30 hrs and during ebb tides of April 1985 and June 1985 series respectively and none appeared in flood tides.
Brachyuran zoeae appeared in large numbers in the 24-h series of April at 02.30 hrs during ebb tide. Anomuran zoeae occurred in August and October 24-h series at 02.30 hrs and before flood tide in both cases at abundance of 3 and 1.5/m^3.

Molluscans (Fig.10) :

(i) Gastropods veligers were collected in all six 24-h series and were found maximum in August 1985 and October 1985 series in abundance of 47 and 77/m^3 at 22.30 and 00.30 hrs respectively (Fig.10).

(ii) Lamellibranch larvae belonging to the oysters _Crassostrea cucullata_ (Born) were found in maximum numbers in the series of April and June at 18.30 and 02.30 hrs in abundance of 12 and 9/m^3 respectively

(iii) _Creseis_ :
Creseis was commonly taken in the plankton of the six 24-h series of December and February during the north-east monsoon, but were rare in the other 24-h series during the south-east monsoon.

DISCUSSION

With respect to egg numbers, all 24-hr series show a similar

pattern. That is, peaks occur around high tides and troughs around low tides, except one neap where high number occured during low tide. In some cases the egg numbers increased two hours after the high tide. The increase in number of eggs may reflect a change in the water mass that is being sampled. The greatest numbers of penaeid larvae occured during flood tides meaning that the post-larval panaeids move from offshore spawning grounds to inshore nursery grounds. There were certain peaks found in between ebb and flood tide; and I cannot conclude that penaeids move to the surface during flood tides in order to facilitate their net movement towards nursery grounds.
Brachyuran zoeae were important numbers of zooplankton after copepods in the 24-hr cycle of April followed by mysis of caridae 14 % .
In the 24-hr series of June 1985 Chaetognath constituted 11 % of the non-copepod sample and followed by fish eggs which constituted about 7 % .
Thalia democratica was recorded in high numbers in the 24-hr series of August 1985. It constituted about 31 % of the non-copepod sample followed by fish eggs.
Gastropod larvae was predominant in the October series with 25 % followed by fish eggs.
In the series of December, Appendicularia made the major contribution to the non-copepod zooplankton with about 50 % followed by Brachyuran zoeae and fish eggs.
Fish eggs contributed as much as 20 % of the total non-copepod density in the 24-hr cycle of February followed by Chaetognath and Brachyuran zoeae.
Paragnathia formica appeared regularly and were of little importance quantitatively. In general the holoplanktonic forms dominated the meroplanktonic forms.
During the 24-h sampling cycle zooplankton consisted both oceanic and creek water origin organisms. Euphasiid and scalps were collected mainly in high tide samples, this perhaps an indicative of a more oceanic origin for the water mass, whereas Lucifer and Acetes showed similar trend and were always found together. Lucifer, Acetes and Ctenophores were collected during low tide which indicate a seaward incursion of creek water.
Salinity was always above 30% , this accounts for the negligible importance of the fresh water at Likoni Ferry.
It is well known that plankton collecting with only one type of net will not sample the total zooplankton community because of the varying size of the plankton organisms (UNESCO, 1986).
However, the Clarke-Bumpus plankton net used here is well suited for obtaining information about the composition of the coastal zooplankton community containing many larval forms of economically important groups. Among the important groups which were obtained in disproportionately low numbers should be mentioned the Penaeid Acetes and the mysids; these two groups can be collected in great numbers when using larval nets (Booruang & Janekarn, 1985).
Quantitative comparisons between data from different zooplankton studies can only be made with great caution because of frequent differences in sampling and particularly the net mesh-size used. This last is well demonstrated by Greenwood (1980).
Greenwood (1980), for example, using a Clarke-Bumpus nets of 195 um pore size recorded total zooplankton abundance of 1691/m^3 and compared between estimates of zooplankton numbers from similar studies elsewhere.

Apart from the work of Reay and Kimaro (1984) no any other work has been published from which to compare the current data from East African inshore studies.
A broad comparison, however, with the work of Reay and Kimaro (1984) who worked in Port Mombasa reveals that the abundance and composition of Macrozooplankton is comparable with the present study. But I cannot compare microzooplankton, their samples were taken with slightly coarser nets than those in the present study and with different method.
In comparison the 24-h sampling cycle in February and March 1983 (Reay and Kimaro, 1984) agrees well with the present study on the results of the 24-h series which demonstrated a clear difference between day and night catches of plankton. The night had higher catches than day.
The zooplankton population is constituted by a large number of species dominated by copepods (Fig. 10) and amongst the copepods calanoids dominated the sample. Decapod larvae mainly brachyuran and caridean zoeae were usually the most abundant crustaceans after the copepods.
Sameoto (1975) showed the relationship between tidal fluctuations and the composition of zooplankton samples at St. Margaret's Bay and concluded that diurnally migrating species of zooplankton did not show a tidal correlation. The tidal efffect has probably a stronger influence on the Likoni Ferry than local rivers entering Port Reitz Creek. It is predicted that any substantial changes in river discharge will affect plankton production in the region.
The influence of land drainage on the Likoni Ferry environment was not reflected on the physical and chemical data. Temperature, dissolved oxygen, pH, SiO_2, and salinity did not fluctuate very much.
Phytoplankton dynamics in this region needs to be looked into and associated with zooplankton dynamics.
Port Reitz Creek (Kilindini) is typical of other tropical coastal waters where plankton community dynamics are controlled primarily by physical factors.

ACKNOWLEDGEMENTS

We thank Prof. Polk for coaching the work and commenting the manuscript, the staff of the Kenya Marine & Fisheries Research Institute; to only mention a few : Messers P. Mathendu, J. Anunda, N. Maroko, J. Kitonga and S. Muiru who assisted on numerous occasions in the field. We thank also the Director of Kenya Marine & Fisheries Institute, Mr. S.O. Allela for his cooperation.
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Table 1 : Zooplankton taxa collected from Likoni Ferry, Mombasa, April 24/25, 1985; August 28/29, 1985; October 30/31, 1985; December 4/5, 1985; and February 25/26, 1986. (51 taxa were identified : xx = abundant, x = common, R = rare).

TAXA	APRIL	JUNE	AUGUST	OCTOBER	DECEMBER	FEBRUARY
ACNIDARIA						
Ctenophora	R					
AMPHIPODA	R	X	R	R	R	R
Hiperiids	R	X	R	R	R	R
ANNELIDA						
Polychaete Larvae	X	R	R	R	R	R
BRANCHIOPODA						
Evadne						
Cladocera		R				
CHAETOGNATHA						
Sagitta	X	X	R	X	R	X
DECAPOD LARVAE						
Anomuran zoeae			R	R		
Brachyuran zoeae	XX	X	R	X	X	X
Brachyuran megalopae	R	R	R	R		R
Caridean larvae	XX	X	R	X	R	X
Pagurid	R					
ISOPOD						
Anilocra	R					
Cryptoniscids	R		R	R		R
Paragnathia larvae.						R
MOLLUSCA						
Bivalve veligers	R	R	X	X	R	R
Creseis	R	R		R	R	X
Gastropod veligers	R	R	X	XX	R	R
Heteropods (atlantid)	R					
Oyster larvae	R	X	R			X
OSTRACODA						
Ostracoda	R	X	R	R	R	R
PENAEIDAE	X					
Lucifer Juvenile	X	X	R	R	R	R
Penaeid mysis	X	R	R		R	R
CHORDATA						
Amphioxus			R	R		
Branchiostoma						
Fish eggs	X	X	X	X	X	X
Fish larvae	R	X	R	R	R	R
Larvacea		R	R	R	X	R
Thalia			XX			
Doliolum	R		R	R	R	R
Appendicularian	R	X	R	X	XX	X
CIRRIPEDIA						
Cirripedia nauplii			X	X	X	R
CNIDARIA						
Hydromedusae		X	R		R	R
Siphonophora	R					
INSECTA						
Halobates			R			
COPEPODA						
Calanoida	XX	XX	XX	XX	XX	XX
Poecilostomatoida	XX	X	X	X	R	X
Cyclopoida	X	X	X	X	X	X
Harpacticoida	XX	X	X	X	R	X
Monstrilloida			R	R	R	
Acetes	R	R	R		R	
STOMATOPODA						
Stomatopod alima		R	R		R	
LOFHOPHORATES						
Bryozoan cyphonautes	R					
CUMACEA						
Cumacean		R	R	R	R	
ECHINODERMATA						
Feather star	R					
Sea urchin larvae	R					
Star fish larvae	R					
FLATYHELMINTHES						
Notoplana (flatworm)	R			R		R
Proboscis-worm					R	
MYSIDACEA						
Hemisiriella		R		R	R	R
PYCNOGONIDA						
Pycnogonid	R					
APHRODITIDAE						
Sea mouse		R		R	R	R

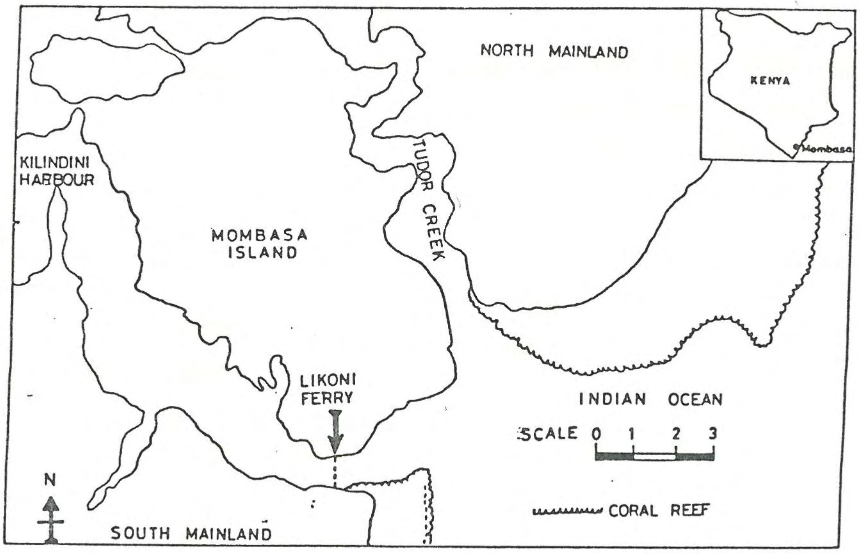

Fig 1. Map of Kenya coast Mombasa showing position of study site at Likoni ferry.

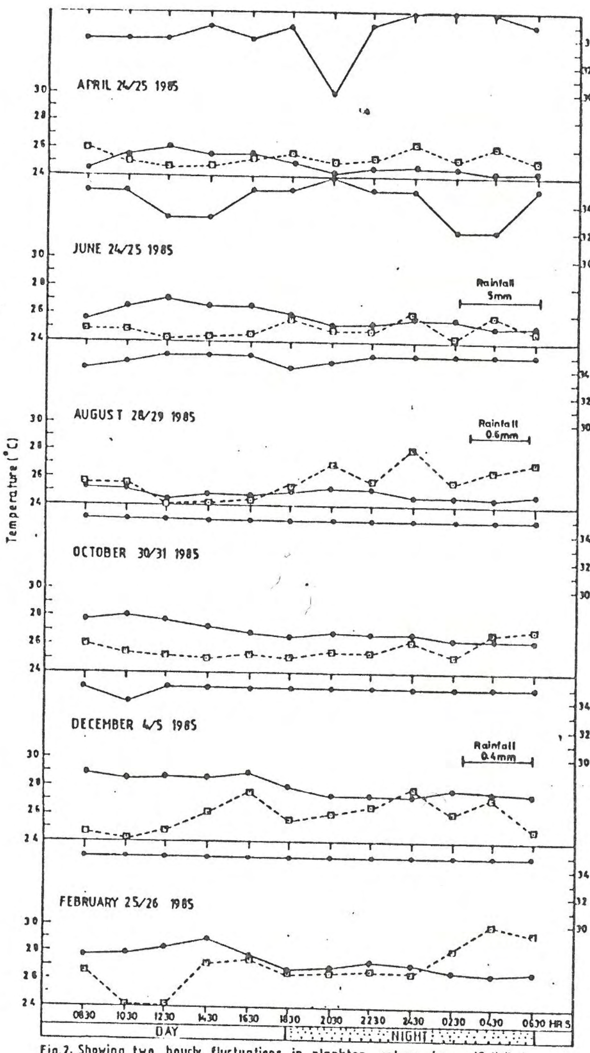

Fig.2. Showing two hourly fluctuations in plankton volume (□---□) Salinity (o——o) and Temperature (•——•) on six 24h, April 24/25 1985, June 24/25 1985, August 28/29 1985. October 30/31 1985. December 4/5 1985. February 25/26 1986.

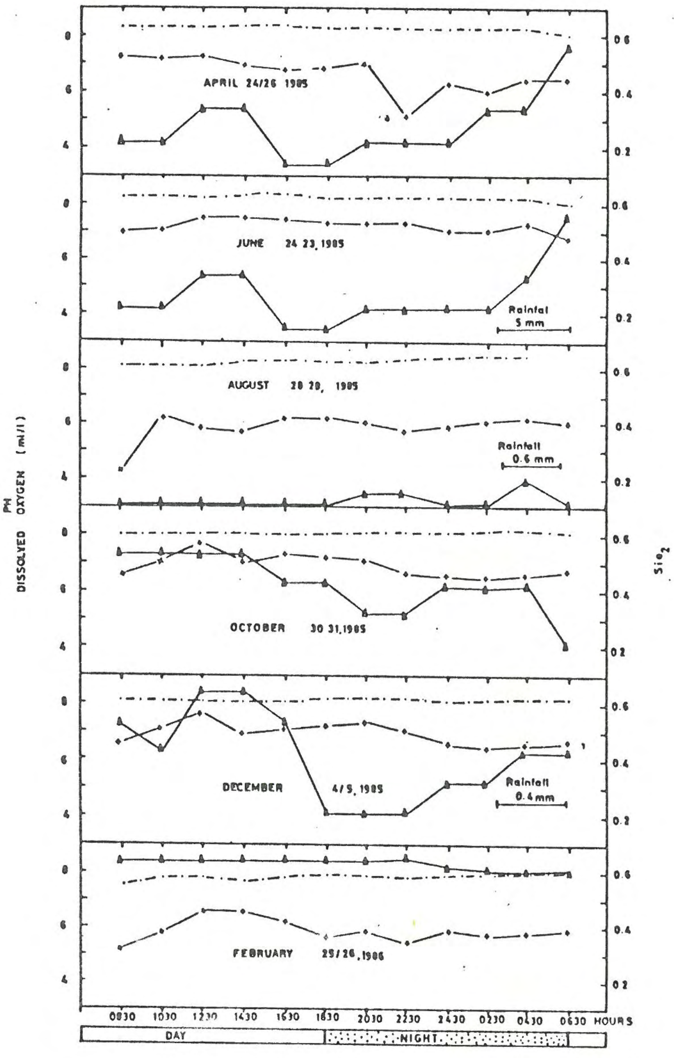

Fig 3 Showing two hourly fluctuations in PH (-·-·-·), Sio₂ (Δ—Δ) O₂ (•--•) on six 24h cycle (April 24/25 1985, June 24/25 1985, August 28/29, 1985, October 30/31 1985, December 4/5, 1985 and February 25/26, 1986)

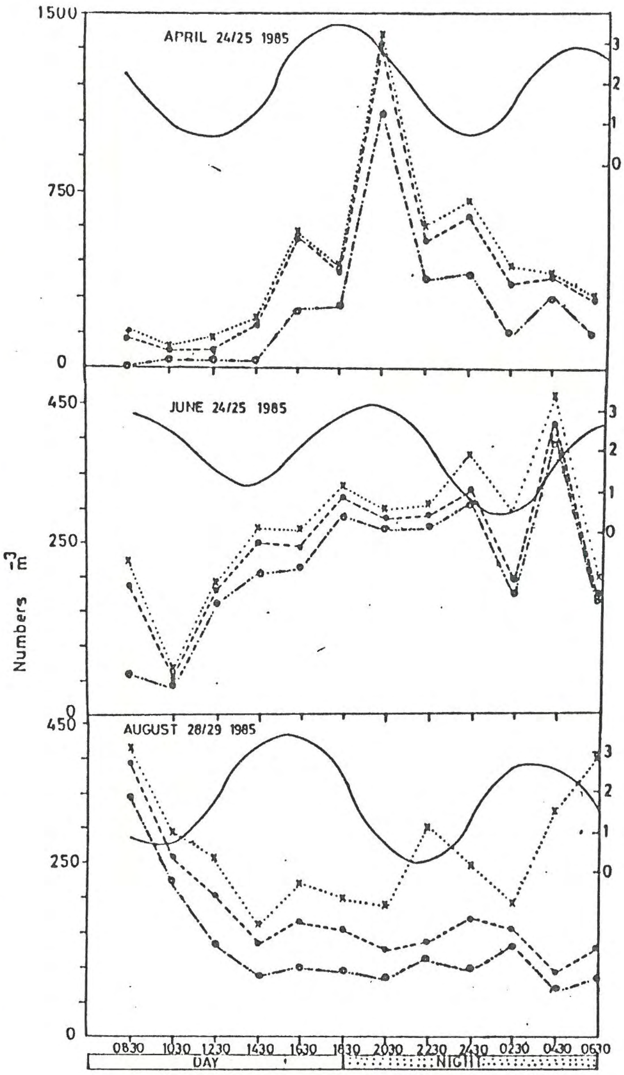

Fig.4 Total Zooplankton (x.....x), Total copepoda (●.....●) and Total calanoida (o.......o) Distribution over period of three 24h, April 24/25 1985, June 24/25 1985 and August 28 29 1985.
Abscissas show time of day (top, hrs) and regime (bottom, stippled area indicates night) tidal height (~)

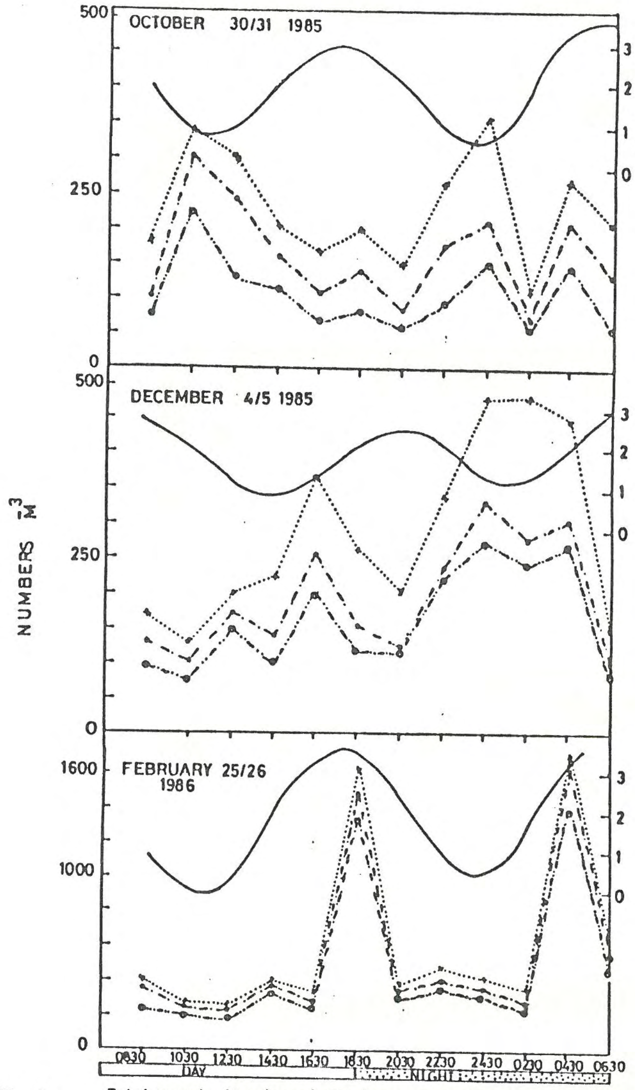

Fig. 5. Total zooplankton (x.....x), Total copepoda (•—·—•) and total calanoida (o.....o) Distribution over period of three 24h, october 30/31 1985, December 4/5 1985 and February 28/29 1986. Tidal height (~). Abscissas as in Fig 4.

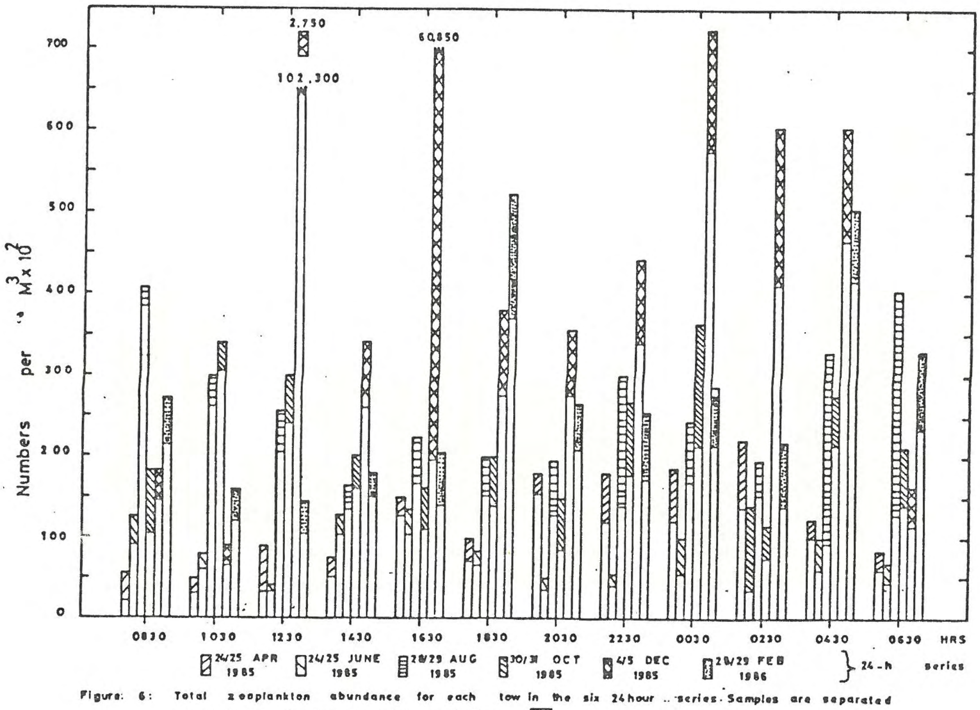

Figure: 6: Total zooplankton abundance for each tow in the six 24hour series. Samples are separated copepods as fraction of total zooplankton: ← Total less copepods. ← Copepods

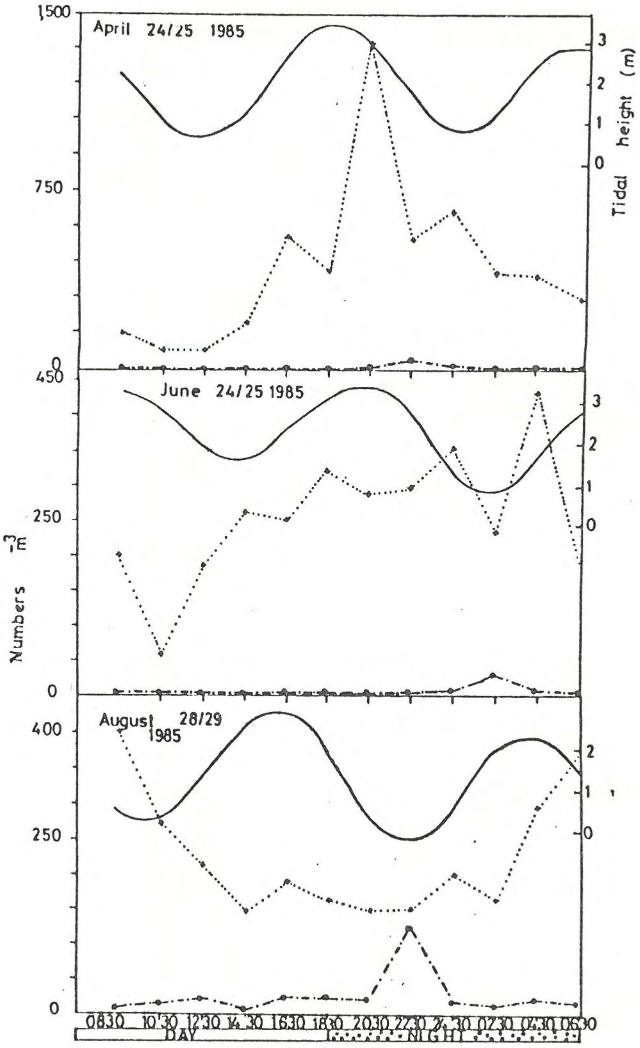

Fig. 7. Total holoplanktonic forms (x......x) and total meroplanktonic forms (•-·-·-•).
Distribution over period of three 24h, April 24/25 1985, June 24/25 1985 and August 28/29 1985.
Tidal height (~).
Abscissas as in Fig. 4.

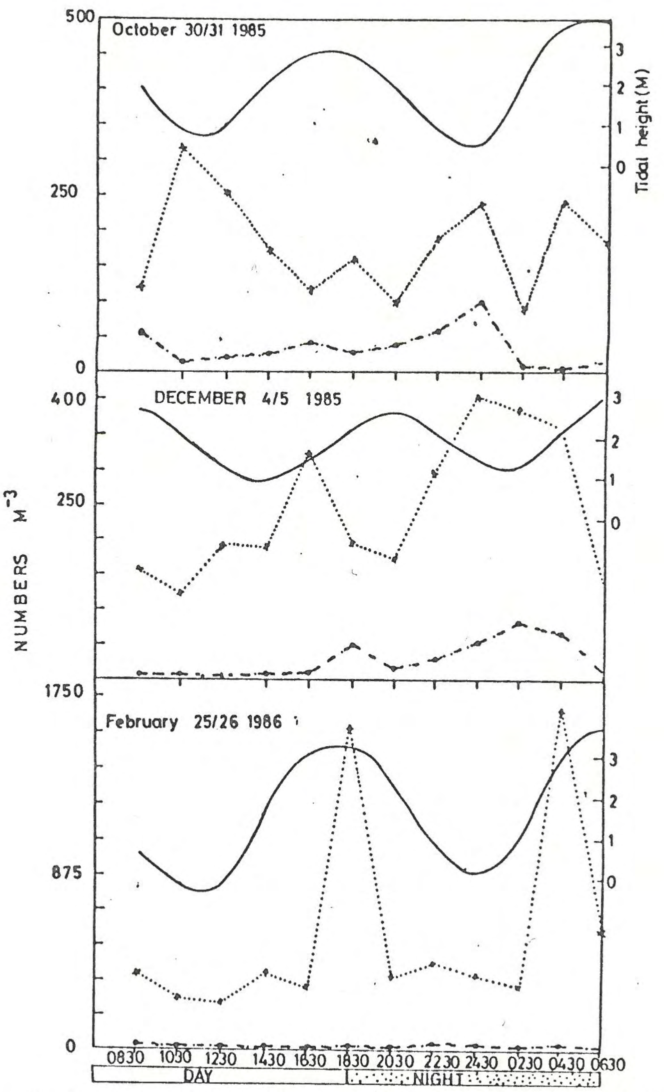

Fig. 8. Total holoplanktonic forms (X......X) and total meroplanktonic forms (•-·-·-•) Distribution over period of three 24h, october 30/31 1985, December 4/5 1985 and February 28/29 1986. Tidal height (~).
Abscissas as in Fig 4.

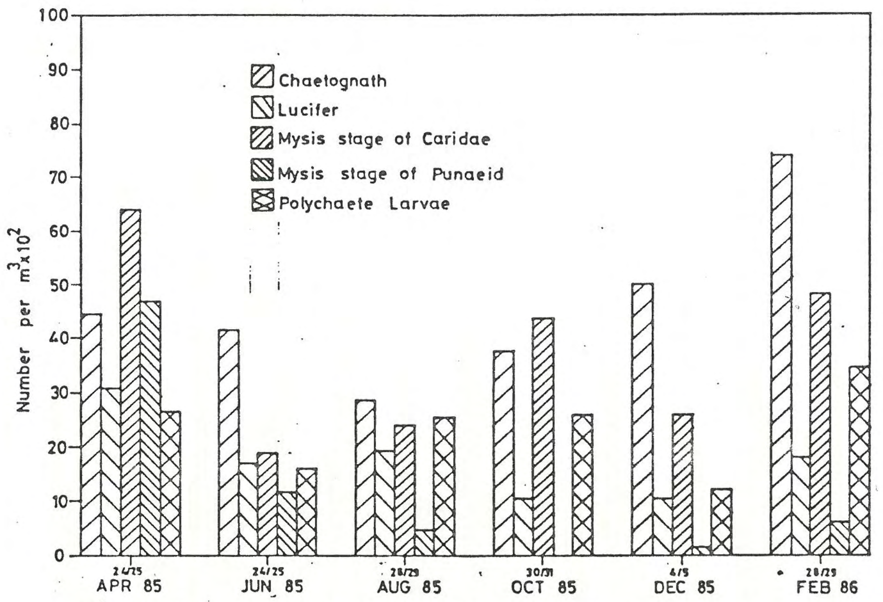

Figure 9 Total zooplankton abundance for each sample in the six 24-hour series.

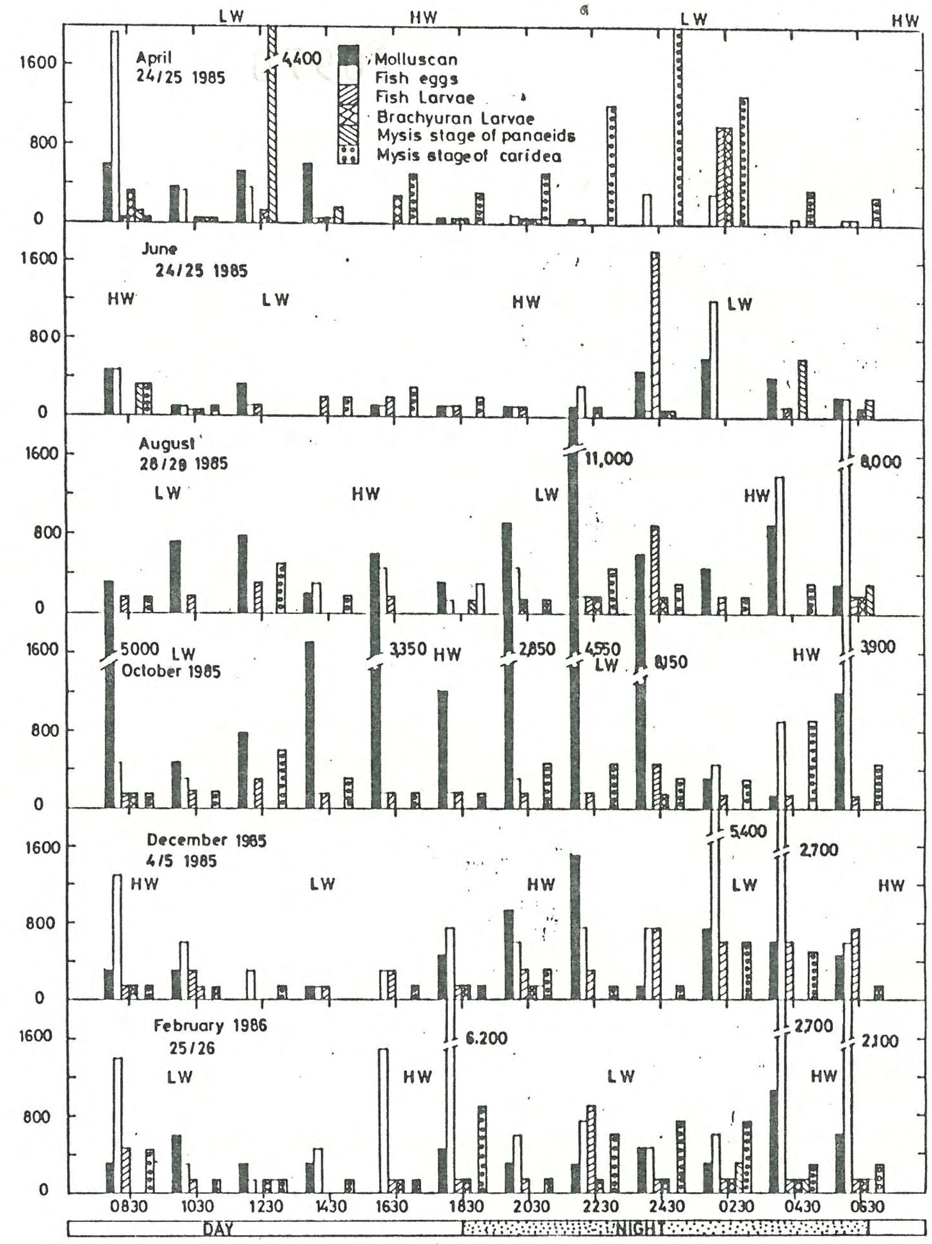

Figure 10. The abundance of selected taxonomic groups in each sample of the 24-h series.

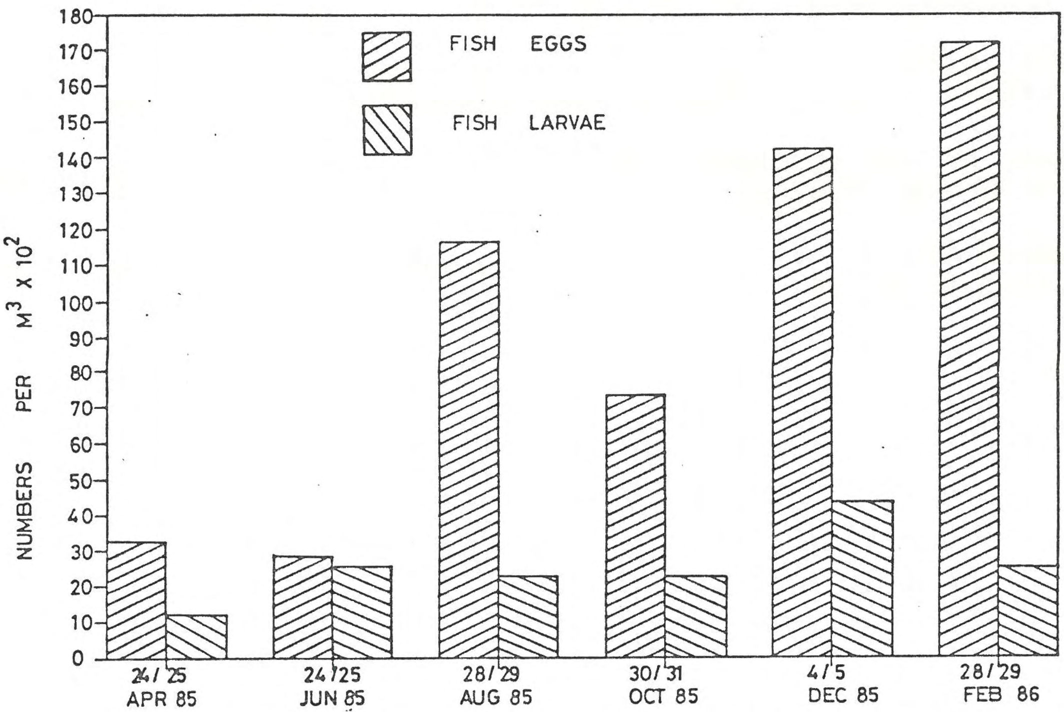

Figure 11: Total fish eggs and fish larvae abundance for each sample in the six 24-hour series.

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2.2.3. MARINE ZOOPLANKTON STUDIES IN TUDOR CREEK. PROGRESS REPORT

M. Kimaro

The inshore and creek waters around Mombasa Island are being studied intensively by the plankton research group of the Kenya Marine and Fisheries Research Institute attached to the Kenya/Belgium Project in Marine Sciences based in the Mombasa Laboratory. Some of the results have already been reported.

In August 1986, I submitted an M.Sc thesis entitled "The Composition, distribution and abundance of near-surface zooplankton in Tudor Creek, Mombasa Kenya," in part fulfilment of the M.Sc Hydrobiology degree of the University of Nairobi. The study set out to determine the seasonal and diel cycles of zooplankton in Tudor Creek, in relation to the prevailing hydrographic conditions (see 2.2.4)

I was involved in the five station plankton sampling program in Tudor Creek. Day and night samples were taken fortnightly on spring and neap tides from September 1985 to September 1986 and thereafter to the present time, samples were taken only during the day on spring tides.

There were several types of nets used for each sampling trip at each station. I used the samples from the 500 um mesh size plankton net for a study on fish eggs and larvae and chaetognaths.

The aim of this study was to investigate the types of fish eggs and larvae and chaetognaths that occur in Tudor Creek as well as their seasonal, tidal and duirnal variations over a period of one year. (February 1986 - January 1987).

The analysis of the samples has been completed, and the data compiled. Presently the data is being analysed with the help of the computer facilities being run by the Computer Section of the Kenya Belgium Project in Marine Sciences.

As soon as the data analysis is completed, the results will be made available in the form of two publications entitled:-

"A study of the ichthyoplankton of near - surface inshore waters of Tudor Creek, Mombasa." and

"The chaetognaths of Tudor Creek, Mombasa; their distribution, abundance and duirnal variation."

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2.2.4. THE COMPOSITION DISTRIBUTION AND ABUNDABCE OF NEAR-SURFACE ZOOPLANKTON IN TUDOR CREEK, MOMBASA KENYA

M. Kimaro

ABSTRACT of M.Sc. Thesis

The composition, distribution and abundance of near-surface zooplankton throughout a one year cycle (November 1984-October 1985) was studied by the analysis of monthly samples taken at three fixed station in Tudor Creek, Mombasa. The biomass was measured by displacement volume of fixed material and the numerical abundance of selected groups was determined using a Bogorov tray under a Wild (M3C) stereomicroscope. The selected groups were chaetognaths, copepods, molluscan larvae, crustacean decapod larvae (excluding brachyuran larvae), brachyuran larvae, fish eggs and fish larvae. Station 1 was located at the mouth of the creek, station 2 was about 2 km from station 1 in the middle reaches of the creek and station 3 was about 2 km from station 2 in the upper reaches of the creek. Zooplankton sampling was carried out by horizontal tows with a plankton net of 335 um mesh size at an approximate depth of 1.3 m. Surface water temperature, surface water salinity and turbidity were measured at the same time as the zooplankton were being collected. On two occasions (24th-25th June, 1985 and 23rd-24th September, 1985) 24 h sampling was carried out at two hourly intervals at a fixed station (English Point) in Tudor Creek, in order to determine the diel cycle of near-surface abundance of the selected groups, using the same small plankton net which was used for the later part of the monthly sampling programme. Surface water temperature, surgace water salinity, pH and the silica content of the water were also monitored during these 24h sampling programmes.

The distribution and abundance of zooplankton and the hydrographic parameters monitored monthly showed seasonal changes closely related with the two monsoon seasons. (northeast monsoon season: November-March; southeast monsoon season: May-September; intermonsoon periods: April and October). The surface water temperature was high during the northeast monsoon with a maximum value of 29.0 C recorded from January to March at all stations. During the southeast monsoon, the surface water temperature declined reaching a minimum value of 26.0 °C at station 1 from July to September and the same minimum at stations 2 and 3 in October. The annual range of surface water temperature at the three stations was therefore small (3 °C) characteristic of tropical waters. The surface water salinity was uniform at 35‰ at all stations during the northeast monsoon, except in February when the maximum value of 36‰ was recorded at all stations. During the southeast monsoon the surface water salinity declined reaching minimum values in May at all stations coinciding with a peak in rainfall. The minimum value differed between stations: 33‰ at station 1, 31‰ at station 2 and 30‰ at station 3. Thus station 1 experienced the least annual surface water salinity change (3‰) whereas station 2 and 3 experienced the largest (5‰ and 6‰ respectively) as would be expected from their locations in the creek. The largest Secchi disc readings were recorded at station 1 and ranged from 12.3 m in December to 2.3 m in June. Smaller Secchi disc readings were recorded at station 2 which ranged from 4.1 m in January to 1.7 m in October.

The smallest Secchi disc readings were recorded at station 3 which ranged from 3.3 m in January to 1.5 m in October. Thus station 1 had the least amount of suspended particulate matter as indicated by the large Secchi disc readings and station 3 had the most as indicated by the small Secchi disc readings.
The selected groups of zooplankton showed different patterns of near-surface abundance in different seasons whereas in the diel cycle, most of the selected groups showed a similar pattern of near-surface abundance. The chaetognaths occurred at all stations throughout the study period and showed maximum abundance during the northeast monsoon was $10/m^3$ ($\pm$ 3.67 SE) at station 1, $8/m^3$ ($\pm$ 2.53 SE) at station 2 and $9/m^3$ ($\pm$ 3.96 SE) at station 3 whereas during the southeast monsoon the values were $3/m^3$ ($\pm$ 0.65 SE) at station 1, $2/m^3$ ($\pm$ 0.20 SE) at station 2 and $3/m^3$ ($\pm$ 0.49 SE) at station 3. Copepods were an important component of the zooplankton especially in samples collected from station 1. Copepods reached maximum abundance values were $154/m^3$ ($\pm$ 44.42 SE) at station 1, $66/m^3$ ($\pm$ 22.78 SE) at station 2 and $90/m^3$ ($\pm$ 60.17 SE) at station 3 during the northeast monsoon and 22/m ($\pm$ 5.55 SE) at station 1, $16/m^3$ ($\pm$ 2.04 SE) at station 2 and 28/m ($\pm$ 14.17 SE) at station 3 during the southeast monsoon. The crustacean decapod larvae (excluding brachyuran larvae) also showed maximum abundance during the northeast monsoon. The mean monthly abundance was $12/m^3$ ($\pm$ 2.53 SE) at station 1, $142/m^3$ ($\pm$ 100.79 SE) at station 2 and $221/m^3$ ($\pm$ 167.91 SE) at station 3 during the northeast monsoon and $18/m^3$ ($\pm$ 2.12 SE) at station 1, $23/m^3$ ($\pm$ 4.44 SE) at station 2 and $22/m^3$ ($\pm$ 6.40 SE) at station 3 during the southeast monsoon. The brachyuran larvae showed a mean monthly abundance of $27/m^3$ ($\pm$ 6.78 SE) at station 1, 292/m ($\pm$ 103.65 SE) at station 2 and $328/m^3$ ($\pm$ 127.90 SE) at station 3 during the northeast monsoon and $186/m^3$ ($\pm$ 112.22 SE) at station 1, $180/m^3$ ($\pm$ 107.77 SE) at station 2 and $155/m^3$ ($\pm$ 72.14 SE) at station 3 during the southeast monsoon. The mean monthly abundance of fish larvae was $2/m^3$ ($\pm$ 0.61 SE) at station 1, $6/m^3$ ($\pm$ 3.31 SE) at station 2 and $3/m^3$ ($\pm$ 1.02 SE) at station 3 during the northeast monsoon and $1/m^3$ ($\pm$ 0.40 SE) at station 1, $2/m^3$ ($\pm$ 0.33 SE) at station 2 and $1/m^3$ ($\pm$ 0.40 SE) at station 3 during the southeast monsoon. The highest abundance of fish eggs was recorded at station 1 which had an equal mean monthly abundance value in both seasons: $4/m^3$ ($\pm$ 0.78 SE) during the northeast monsoon and $4/m^3$ ($\pm$ 0.73 SE) during the southeast monsoon. Station 2 and 3 had lower numbers of fish eggs during the northeast monsoon than during the southeast monsoon. During the northeast monsoon the mean monthly abundance value was the same for both stations: $1/m^3$ ($\pm$ 0.20 SE) at station 2 and $1/m^3$ ($\pm$ 0.69 SE) at station 3. During the southeast monsoon the mean monthly abundance value was $6/m^3$ ($\pm$ 3.84 SE) at station 2 and $3/m^3$ ($\pm$ 0.69 SE) at station 3. The molluscan larvae which were comprised mainly of gastropod larvae showed a higher mean monthly abundance during the southeast monsoon than during the northeast monsoon. The mean monthly abundance was $4/m^3$ ($\pm$ 1.33 SE) at station 1, $3/m^3$ ($\pm$ 1.02 SE) at station 2 and $1/m^3$ ($\pm$ 0.32 SE) at station 3 during the southeast monsoon and $1/m^3$ ($\pm$ 0.98 SE) at station 1, $1/m^3$ ($\pm$ 0.53 SE) at station 3 during the northeast monsoon.

The peaks in numbers of the selected groups and the zooplankton biomass exhibited a pattern closely related to the rainfall pattern. There were three major peaks in numbers in December, March/April and June at all stations. There were two major biomass peaks in December and April, and minor peaks in July/August at all stations. The peaks in December occurred after the short rains in November. The peaks in March/April occurred after the onset of the long rains in March. The major peak in numbers in June and the minor peaks in biomass in July/August occurred after peak rainfall in May. Probably the increased nutrient input into the creek due to increased fresh-water input from the rivers with a high content of land derived nutrients during heavy rainfall periods enhances phytoplankton production which inturn leads to increased numbers and biomass of zooplankton in the peaks that we see. The lag time between heavy rainfall and zooplankton production was about two to four weeks. The numbers and biomass reached the lowest values during the dry months of both seasons: January - February in the northeast monsoon.

The diel range of surface water temperature was 2 °C in June and 1.5 °C in September. The lowest temperatures were recorded at night and the highest during the day on both occassions. The diel range of surface water salinity was 1/oo on both occasions with the lower value (34‰) being recorded at night. The highest values of the silica content of the water were recorded at 10.30h and 03.30h in June and at 07.30h and 17.30h in September. The silica values recorded in June were higher (0.08 ppm - 0.20 ppm) than those recorded in September (0.06 ppm - 0.10 ppm). The pH values ranged from 8.05 (07.30h) to 8.31 (11.30h) in June and 8.30 (07.30h) to 8.6 (11.30h) in September. The pH values recorded in June were lower than those recorded in September.

There was less zooplankton caught near the surface during the day than during the night on both occasions. Most of the selected groups of zooplankton showed maximum near-surface abundance between 19.30h and 23.30h on both occasions. The pattern observed was accounted for by the classical pattern of vertical migration. The results point firstly to light as the major timing factor and secondly, that the tidal cycle has no discernable effect on the diel cycle of near-surface abundance of zooplankton.

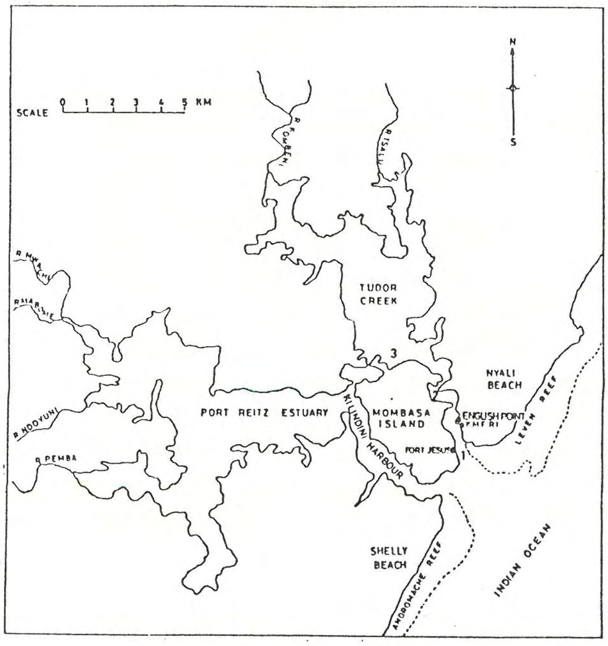

Figure 1.1: The creeks and estuaries adjacent to Mombsa Island. The monthly sampling stations (1, 2 and 3) and the 24 hour sampling station at English Point in Tudor Creek are shown.

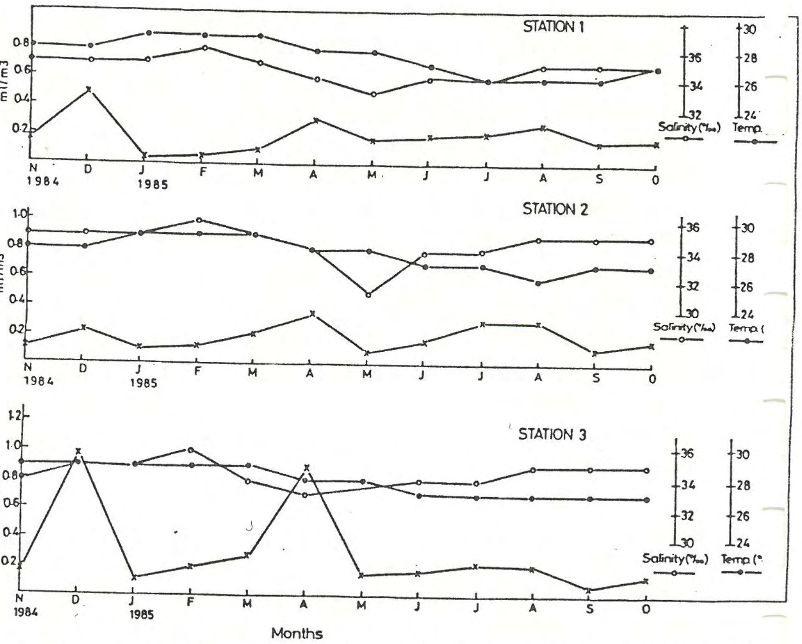

Figure 3.1: Monthly variations in zooplankton biomass and hydrographic parameters at three fixed stations in Tudor Creek, Mombasa.

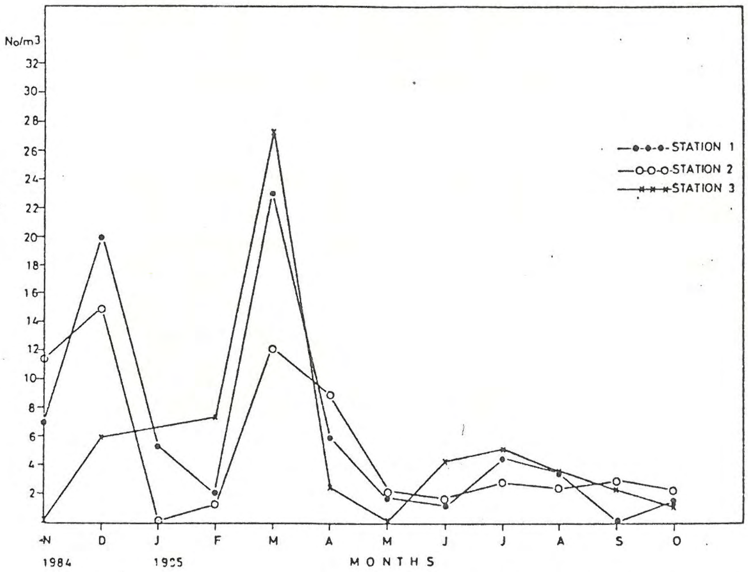

Figure 3.4: Abundance of Chaetognatha at three fixed stations in Tudor Creek, Mombasa.

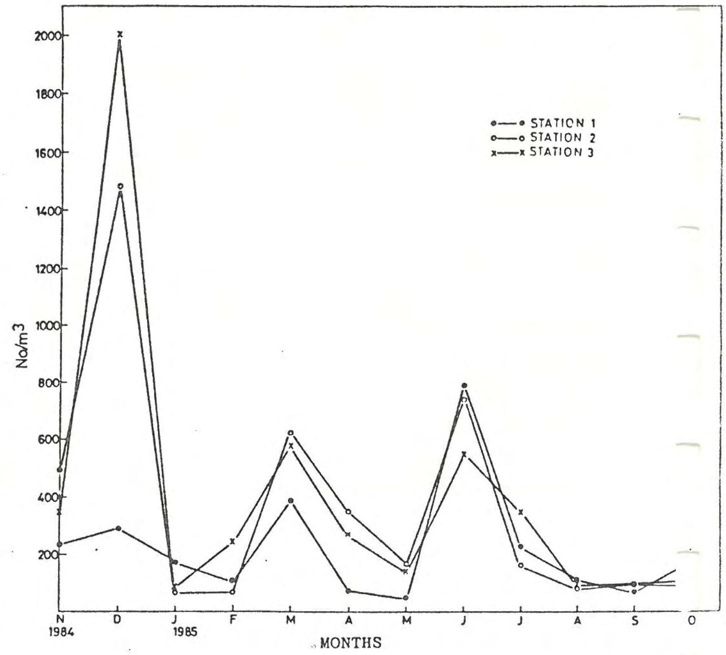

Figure 3.3: Variations in the total abundance of selected gr ups of zooplankton at three fixed stations in Tudor eek Mombasa.

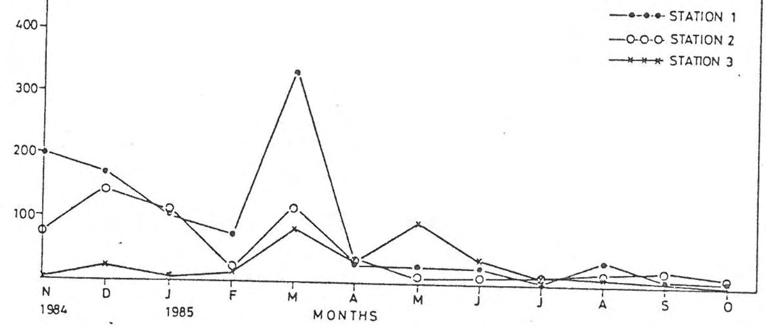

Figure 3.5: Abundance of Copepoda at three fixed stations in Tudor Creek, Mombasa.

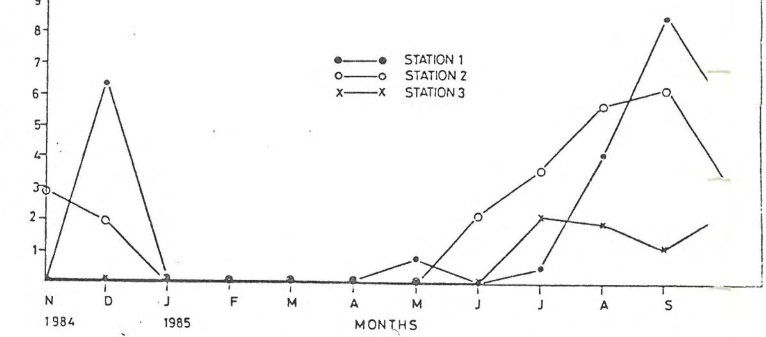

Figure 3.6: Abundance of molluscan larvae at three fixed stations in Tudor Creek, Mombasa.

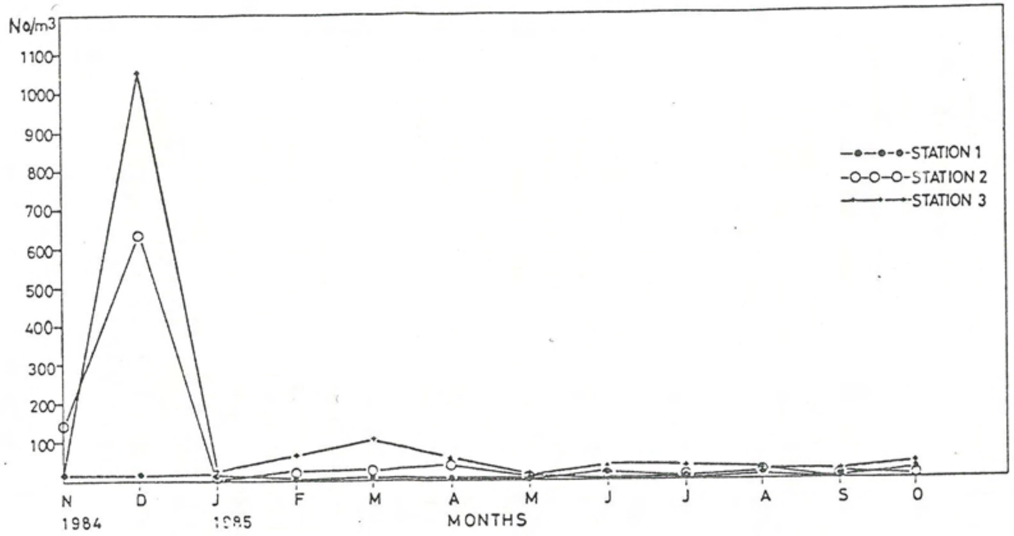

Figure 3.7: Abundance of crustacean decapod larvae (excluding brachyuran larvae) at three fixed stations in Tudor Creek, Mombasa.

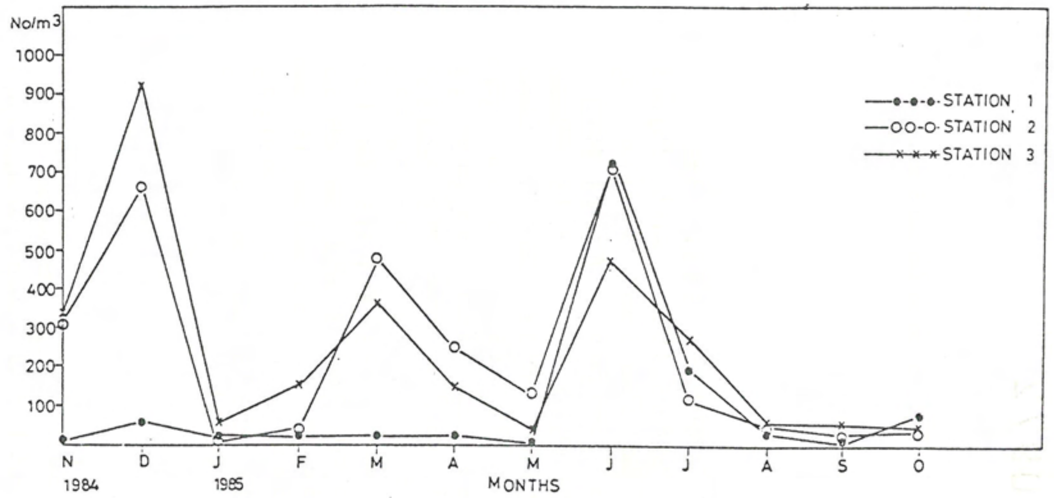

Figure 3.8: Abundance of brachyuran larvae at three fixed stations in Tudor Creek, Mombasa.

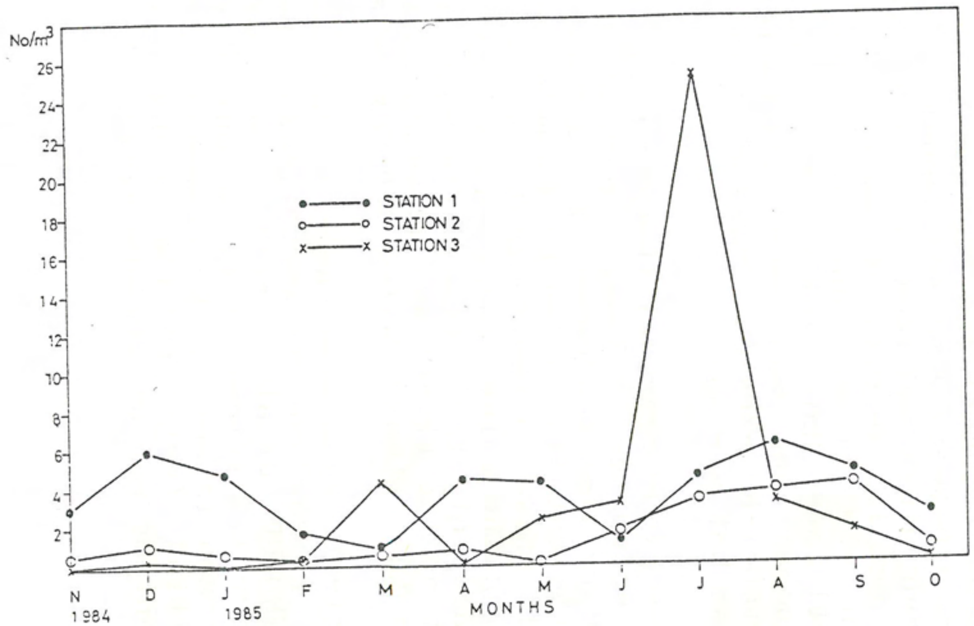

Figure 3.9: Abundance of fish eggs at three fixed stations in Tudor Creek, Mombasa.

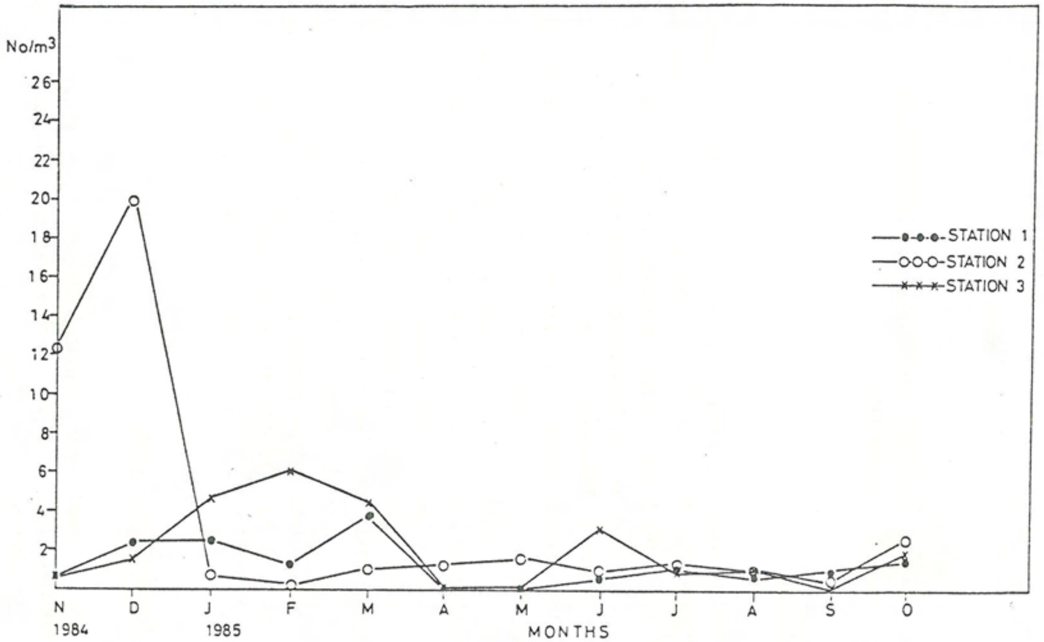

Figure 3.10: Abundance of fish larvae at three fixed stations in Tudor Creek, Mombasa.

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3. CHEMICAL RESEARCH

3.1. SEASONAL FLUCTUATION OF NITRATE-NITROGEN CONCENTRATION IN TUDOR ESTUARY, MOMBASA

J.M. Kazungu

SUMMARY

Nitrate-nitrogen seasonal fluctuation in Tudor estuary is investigated with data collected between April 1986 and March 1987. While the rivers are indicated to be the main source of the nitrate-nitrogen during the long rainy season (April-May), the Coast General Hospital's Sewage System (C.G.H.S.S.) is shown to be its main source during the dry season (July-Sept.) that follows. During the short rainy season (Oct.-Dec.) both the rivers and the sewage system are involved in the supply of nitrate-nitrogen into the estuary. Profiles for the dry season that follows the short rains again shows the C.G.H.S.S. to be the only source of nitrate-nitrogen in the estuary during this period. Infact hardly any nitrate-nitrogen is found at the stations which are most upstream. Nitrate-nitrogen is therefore suggested to be one of the parameters which would most likely act as a limiting factor for phytoplankton growth at the most upstream water body of the estuary during this particular dry period.

1. INTRODUCTION

Due to pressure imbalances in the Indian Ocean, two popular monsoonal seasons, namely, the northeast and southwest monsoons are created. The northeast monsoons are mainly experienced between December and February while the southwest monsoons are strong between June and August (TCHERNIA, P., 1980). Because of strong winds and lack of rain during this time, these two periods are usually referred to as dry periods. Long rains are experienced when the winds change from northeast to southwest (mainly in April and May) while short rains come after the southwest monsoons but just before the beginning of the northeast monsoon (October-November). The two rainy seasons are sometimes referred to as wet periods.

These four seasonal changes normally have an adverse effect on estuaries. Tudor Creek which is mainly a tidal mangrove estuary lies northwest of the Mombasa Island. The northern part of the estuary is fed by a number of rivers from the neighbouring hills while to the south it is open and joins the Indian Ocean. During the rainy season, a lot of nutrients and organics are washed into the estuary (KAZUNGU, et al. 1987, in press). Since most of the rivers are seasonal hardly any nutrients are supplied into the estuary during the dry seasons.

Nutrients have been shown to influence and at times control the production of phytoplankton both in the oceans and lakes (SVERDRUP, et al., 1942). Their availability may therefore play a very significant role in controling primary productivity. Nitrogen is one of the elements which commonly acts as a major limiting factor for phytoplankton growth. Though phytoplankton organisms may assimilate different compounds of nitrogen, (mainly

nitrates, nitrites, and ammonia), nitrates are cited to be the most important (SVERDRUP et al., 1942).
This paper reports on the seasonal fluctuations of nitrate-nitrogen concentrations in the Tudor estuary. This is part of an ongoing Kenya-Belgium Oceanographic project on the identification of various water types existing in Tudor estuary. The data was collected mainly between April 1986 and March 1987.

2. MATERIAL AND METHODS

Fig. 1 shows the sampling stations for the Tudor estuary.
Sampling was done bi-weekly except on few occasions when this was not possible. All samples were collected during low tide. In this paper, only surface samples are analysed and discussed.

Samples for the nitrate-nitrogen determinations were collected in one litre plastic bottles and fixed with 1-ml mercuric chloride (50g/1000ml) before being placed in Ice-Boxes.

Chemical analysis was done mainly by applying the modified version of the Morris and Riley method as suggested by Parsons et al.,(1984). This method involves the heterogeneous reduction of nitrate to nitrite (by passing it through a coppernized Cadmium reductor) followed by diazotization and coupling to form a coloured azo dye complex that is measured spectrophotometrically.

Efficiency of the Reduction Column

Fig. 2 shows a sketch drawing of the reduction column used.
For testing the efficiency of the columns, nitrate and nitrite solutions of the same concentration (6.0 µg at N/l) were prepared from sodium nitrate and sodium nitrite respectively. Ten samples of the nitrate solution were then passed through the reduction column before being subjected to the diazotization and coupling reactions. For complete reduction of the nitrate solution to have occured, the absorbance of the resultant nitrite solution after diazonation and coupling is expected to be the same as that obtained from the sodium nitrite solution.
The average efficiency obtained for the columns was 96.5%

3. RESULTS AND DISCUSSION

For interpretation purposes, the results have been grouped and placed into four periods each covering a particular season.

These periods are;

(i) April - June 1986 - covers the long rainy season.

(ii) July - September 1986 - covers the dry season after the long rains.

(iii) October - December 1986 - covers the short rainy season

(iv) January - March 1987 - covers the dry season after the short rains.

(i) April - June (1986) period

Fig.3 shows the nitrate-nitrogen distribution profiles of Tudor estuary stretching from April to June 1986. This covers the long rainy season of April - May. At the beginning of the rainy season (22/4/86 profile) a nitrate gradient with low values near the open sea and higher values upstream developed. The highest concentrations of nitrate-nitrogen were recorded in May which also corresponded with the rainfall peak (fig.7). The profile for early June indicated a reduction in nitrate-nitrogen concentrations throughout the estuary. Towards the end of June, the effect of the rivers was found to be quite minimal for the supply of nitrate-nitrogen into the creek. However a small peak was detected at St.A2. This peak is due to the Coast General Hospital's Sewage discharge (KAZUNGU, et al.1987).

(ii) July - September (1986) period

Immediately after the long rains a dry period follows. Fig.4 shows the nitrate-nitrogen distribution profiles during this period. All peaks are detected at St. A2 and therefore the only source of nitrate-nitrogen within the estuary during this period seems to be the Coast General Hospital's Sewage System (C.G.H.S.S.). Maximum concentrations are different for each peak due to the fact that the sewage supply into the estuary is not uniform. It is interesting to note that due to this local source, nitrate-nitrogen concentrations for most of the stations upstream (after St.A3) have less than 1.0 µg-at N/l while the concentrations around St. A2 vary between 1.0 µg-at N/l and 4.0 µg-at N/l.

(iii) October - December (1986) period

Fig.5 shows the nitrate-nitrogen distribution patterns for the estuary during the short rains. Unlike the patterns observed during the long rainy season (fig.4) where the sewage effect was overshadowed by the rich-nutrient waters from the rivers upstream, during the short rains, there is a less supply of nitrates from the rivers and hence both the sewage effect and the rivers are significant for the supply of nitrate-nitrogen into the estuary. As a result, a more or less uniform nitrate-nitrogen water body is established throughout the estuary (ref. profiles of 25/11/86, 15/12/86 and 30/12/86). It should be noted that these concentration levels are relatively very low compared to those observed during the long rains. Nitrate-nitrogen concentrations for 30/12/86 are observed to be relatively higher than the rest in that season. This corresponds with the rainfall peak observed in December (fig.7).

(iv) January - March (1987) period

Nitrate-nitrogen distribution patterns for the dry season that follows after the short rains are shown in fig.6. The C.G.H.S.S. is again identified as the only source of nitrate-nitrogen in the creek. However, unlike the other dry season, "river's effect" disappears completely and except for the 03/03/87 profile, all the other profiles indicate that there was hardly any nitrate-nitrogen after St. A5.

4. CONCLUSION

Whereas Tudor Creek is sometimes referred to as an estuary, past work revealed that this is so only during the long rainy season. During this season, rivers are identified to be the main source of nitrate-nitrogen in the estuary. The highest concentrations are found in May which also corresponds with the rainfall peak. During the dry period that follows, the Coast General Hospital's Sewage System (C.G.H.S.S.) is identified as the main supply of nitrate-nitrogen in the Creek. Whereas the nitrate-nitrogen concentration around St.A2 oscillates between 1.0 µg-at N/l and 4.0 µg-at N/l, almost all nitrate values upstream (after St.A3) are found to be below 1.0 µg at N/l. During the wet period (short rains) that follows this dry period, both the rivers and the sewage system are found to play a significant role for the nitrate-nitrogen distribution within the estuary. Unlike in the long rainy period, the nitrate-nitrogen supply into the estuary is very small during the short rains. So the river contribution together with the sewage gives more or less uniform nitrate values throughout the estuary. However these nitrate concentrations are relatively very low compared to those observed during the long rainy season. Nitrate-nitrogen profiles for the dry period that follows the short rains are similar to those of the earlier dry period (July-September) confirming the supremacy of the C.G.H.S.S. as the only source of nitrate-nitrogen in the entire estuary during these periods. However, during this particular dry period, hardly any nitrate-nitrogen was observed upstream (after St.5). In this case, nitrate-nitrogen, by acting as a limiting factor for phytoplankton growth, may affect the primary productivity for the body of water which is most upstream during this dry season.

5. ACKNOWLEDGEMENTS.

I wish to express my gratitudes to Mr. S.O. Allela, Prof. Ph. Polk and Dr. E. Martens, Dr. F. Dehairs and Dr. L. Goeyens for their valuable suggestions. I am particularly thankful to Mr. J. Kamau, C. Mittow and S. Tunje for assisting me with the data collection.

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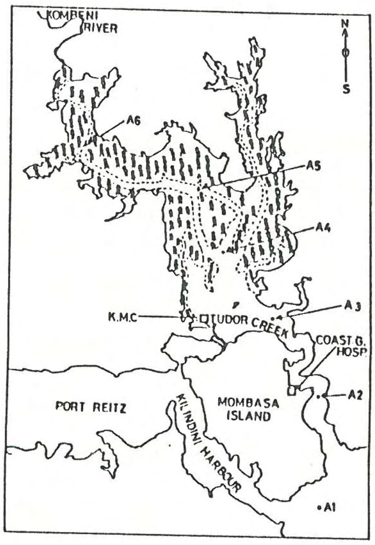


Fig. 1. Sampling stations (A1-A6) for the Tudor estuary.

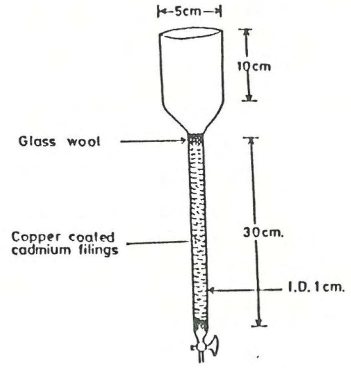
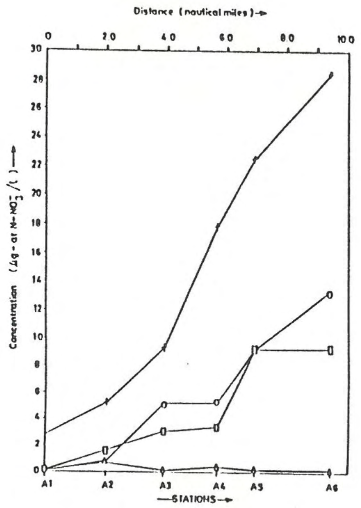
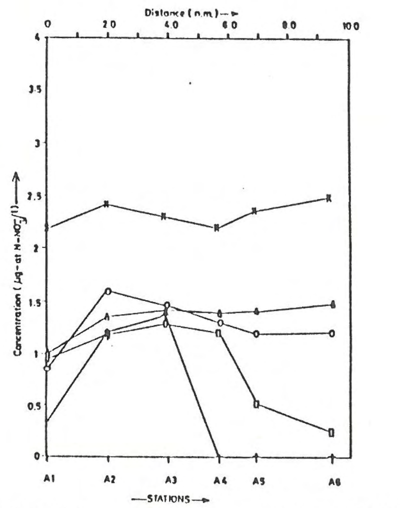


Figure 2. Sketch drawing of the type of Reduction column used.



□ 27/4/86 + 22/5/86 o 4/6/86 Δ 24/6/86

Figure 3. Nitrate - nitrogen distribution profiles of Tudor estuary (April-June' 86)



□ 7/10/86 + 12/11/86 o 25/11/86 Δ 15/12/86 x 30/12/86

Figure 5. Nitrate - nitrogen profiles of Tudor estuary (Oct. - Dec. ' 86)

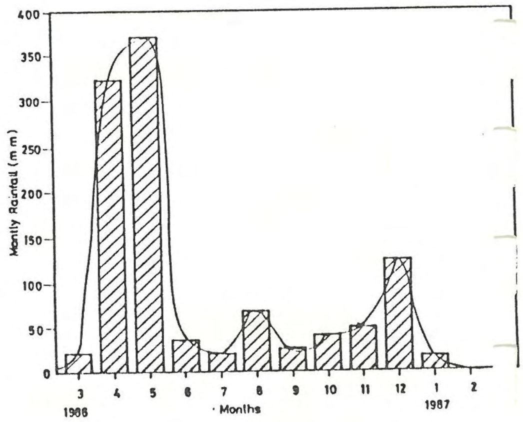
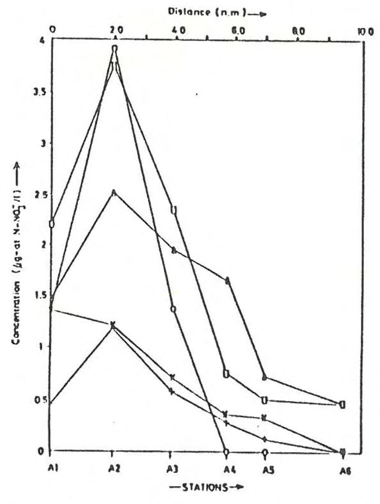
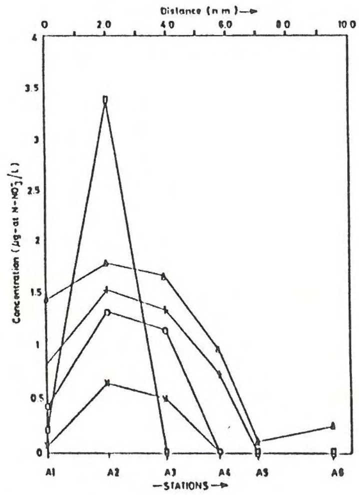


Figure 7. Monthly rainfall Bar chart for Mombasa (Mar. ' 86 - Mar. ' 87).



□ 8/7/86 + 24/7/86 o 5/8/86 Δ 20/8/86 x 15/9/86

Figure 4. Nitrate - nitrogen profiles of Tudor estuary (July - Sept. ' 86)



□ 27/1/87 + 11/2/87 o 25/2/87 Δ 3/3/87 x 17/3/87

Figure 6. Nitrate - nitrogen profiles of Tudor estuary (Jan. - Mar. ' 87).

3.2. NUTRIENTS DISTRIBUTION PATTERNS IN TUDOR ESTUARY DURING RAINY SEASON

. Kazungu J. M. (KMFRI - Mombasa); Dehairs, F. and Goeyens, L. (Free Univ. Brussels)

SUMMARY

Nutrients distribution pattern for the Tudor Creek, covering the period April, May, June and July (1986) is investigated. It is noticed that on the beginning of the rainy season (April), a salinity gradient develops within the creek. This gradient has low salinity values upstream and high values towards the open sea. At this time the creek acquires estuarine characteristics. After the rainy, season, salinity values become more-or-less uniform throughout the creek. The low salinity waters near the river mouths situated near the beginning of the creek, were found to have high nutrient concentrations which decreased gradually towards the open sea. The highest nutrient concentrations were recorded in May which also corresponded with the rainfall peak. From the analysis, it is therefore found that a lot of nutrients (Nitrate, Silicate and Phosphates) are washed into the estuary by the rivers during the rainy season. The Coast General Hospital's sewage drainage system is also identified as one of the local sources of nutrient supply into the estuary. However, its effect is not noticed during the peak of the rainy season due to the rich nutrient waters from the rivers upstream.

1. INTRODUCTION

A nutrient element is defined as one which is functionaly involved in the processes of living organisms. Though the term has been applied almost exclusively on Silicon, Phosphorus and inorganic nitrogen, strictly speaking, a number of the major constituents of sea water, together with a large number of essential trace metals are also nutrient elements. Silicon, Phosphorus and inorganic nitrogen occur in sea water in low concentration and at times are known to act as limiting factors for Phytoplankton growth. Availability of these elements therefore plays an essential role in controling primary productivity. Due to mixing and advetive processes in the seas and oceans, the location of the sources and sites at which an element is removed from solution will cause gradients in concentration and produce particular Distribution Pattern.

Tudor Creek (fig.1) forms the north-western boundary of the Mombasa Island. It is approximately 10 nautical miles long. The characteristics of the creek are such that during the rainy season, a salinity gradient develops due to river drainage system upstream. The creek them acquires Estuary characteristics. However during the dry season salinities become more-or-less uniform throughout the creek (Norconsult report, 1975). Because of these seasonal changes, different water types are likely to exist within the estuary. Okemwa and Revis (1987 in Press), reports that certain copepods species are common in certain areas of the estuary and not in others. This could be evidence of the existance of different water types within the estuary.

The aim of the present paper is to report on the influence of river drainage on the nutrients distribution within the estuary during the long rain season (April - May 1986). This is part of an ongoing Kenyan/Belgium Project on the identification of various water types within the Tudor and Kilindini estuaries.

2. MATERIAL AND METHODS

Fig. 1 shows the sampling stations for the Tudor estuary. Station A 1 represents the open sea water while station A6 is the farthest station upstream of the Tudor estuary - near the river mouths.

Samples were chemically fixed immediately after collection and stored in ice boxes at temperatures below 5 °C. On return to the laboratory, phosphate and silicate samples were analysed immediately while nitrate samples were deep frozen and analysed the following day. Nitrate samples were collected in one liter plastic bottles and fixed with 1 ml mercuric chloride (50g/1000 ml) before being put into the ice box. Samples for the phosphate and silicate determinations were collected in a one liter plastic bottle and fixed with 5 ml chloroform. Salinity determinations were done using the Borlis titration method. Analystical procedure followed for the nutrients determination are as described in Parsons et al (1984).

3. RESULTS AND DISCUSSION

Results of the nutrients (Nitrate, Silicate and Phosphate) and salinity distribution for the Tudor estuary are presented in fig.2 to 5. Its clearly observed that river runoff during the rainy season has a profound effect on the nutrients distribution pattern in Tudor estuary.

3.1. Nitrate Distribution

Fig. 2 shows the nitrate distribution within the estuary. On the start of the rainy season (fig.8, April), high nitrate values were observed at station A5 and A6 than at any other station within the estuary. Nitrate concentrations reduced gradually downstream and the lowest concentrations were recorded at station A1. The highest nitrate concentration for this period was about 9.4 ug -at N/1 recorded at A6 while the lowest was about 0.2 ug-at N/1 observed at station A1.

In may, at the peak of the long rains (fig.8) nitrate concentrations were relatively higher compared to the previous month. Again the distribution trend was similar to that of April with the highest value (22.6 µg-at N/1) recorded at st. A6 and the lowest (2.75 µg-at N/1) recorded at at. A1. In June and July, after the rains had stopped, nitrate concentrations fell so low (<1.0 µg-at N/1)) throughout the estuary. The two small peaks recorded at st. A2 during these two months are most probably due to the sewage system from the Coast General Hospital. During the months of April and May, the sewage effect is overshadowed by the night nutrient waters from the rivers.

3.2. Silicate Distribution

Fig. 3 shows silicate distribution along the Tudor Creek. Higher Silicate concentrations are all observed near the river mouth. In April, at the beginning of the rainy season, the highest concentration was about 71.0 µg-at Si/1 at station A6 while the lowest concentration (3.5 µg-at Si/1) was recorded at st. A1. The May Silicate profile shows a very pronounced influence of the river runoff into the estuary. Silicate concentrations of above 180 µg-at Si/1 were recorded at stations A5 and A6. Station A1 also had relatively higher values (Ca. 22.0 µg-at Si/1) than the previous month. In June and July, after the end of the rainy season, silicate concentrations dropped very sharply .

3.3. Phosphate Distribution

Phosphate distribution pattern was similar to that of silicate. Higher phosphate concentrations were recorded at st. A6 in April and May while st. A1 had the lowest during this period (fig. 4). Whereas as high as 2.0 µg-at P/1 was recorded at st. A6 in May, in June and July phosphate concentrations throughout the creek were below 1.0 µg-at P/1.

3.4. Salinity Distribution

The salinity profiles for Tudor estuary (fig. 5) confirms the fresh water influence into the creek. In April, the salinity profile showed a sharp gradient from st. A1 to A6. Whereas st. A1 had a salinity of about 36.2% typical of oceanic water, salinity for station A6 was below 2%. In May, salinities were relatively lower throughout the creek with the lowest recorded at st. A6 near the river mouth. Comparing these two salinity profiles with those of nitrate (fig. 2) and silicate (fig. 3), it is observed that the high concentrations of nitrate and silicate at st. A6 corresponds to the low salinity waters from the rivers. In June, the salinity gradient decreased considerably while in July, salinities throughout the creek were more-or-less uniform.

Figs. 6 and 7 show profiles of nutrients against salinity for the months of May and June respectively. Whereas the Phosphate and Nitrate peaks are clearly observed at st. A2 in June, they are not observed in May. These peaks are most probably due to the sewage drainage system (near st. A2) from the Coast General Hospital. The peaks are not observed in May due to a large river runoff into the estuary whereby nutrients brought in by the rivers overshadows the sewage effect.

4. CONCLUSION

Nutrients distribution pattern for the Tudor estuary indicates a very strong influence of river discharge into the estuary during the rainy season. The highest nutrients concentrations were recorded in May during the peak of the rainy season. As high as 186.00 µg-at Si/1, 22.6 µg-at N-NO /1 and 2.0 µg-at P/1 were recorded for silicate, nitrate and phosphate respectively during this month. All these high values were observed near the river mouths and decreased gradually towards the open sea. After the month of May, nutrient concentrations dropped sharply and with the exception of st. A2 which showed a small peak, all nitrate and phosphate concentrations were more-or-less uniform throughout the estuary. The peak at st. A2 could be due to a local source of nutrients within the estuary. Since st. A2 is close to the sewage drainage system from Coast General Hospital, it is most probable that the peak is caused by the sewage effect. This sewage effect is not detected in May due to the rich nutrient waters from the rivers upstream.

5. ACKNOWLEDGEMENTS

The authors wish to express their gratitude to Mr. S.O. Allela - Director of Kenya Marine anf Fisheries Research Institute and Prof. Ph. Polk - Director of the Kenyan-Belgian Project in Marine Sciences and Dr. E. Martens, for their valuable suggestions. We would also like to thank Moi International Airport Meteorological department for availing their rainfall data to us.

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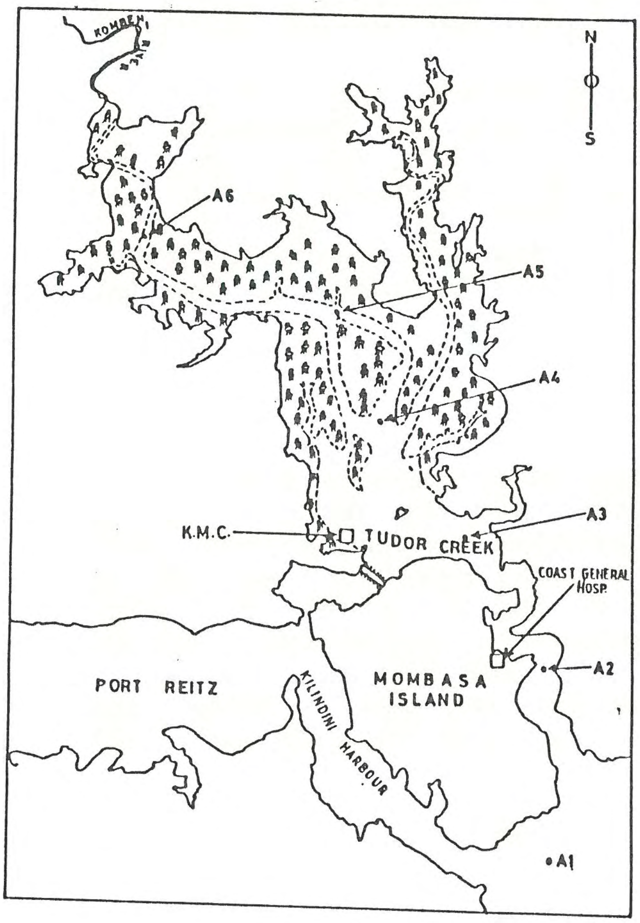

Fig. 1. Sampling Stations (A1 - A6) for the Tudor estuary.

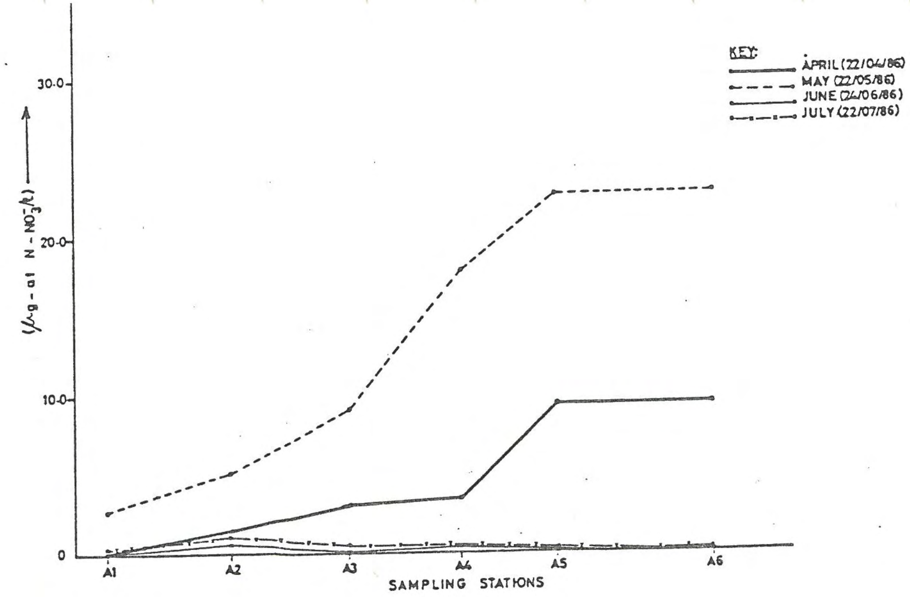

Fig. 2. Nitrate distribution patterns in Tudor estuary for April, May, June and July (1986).

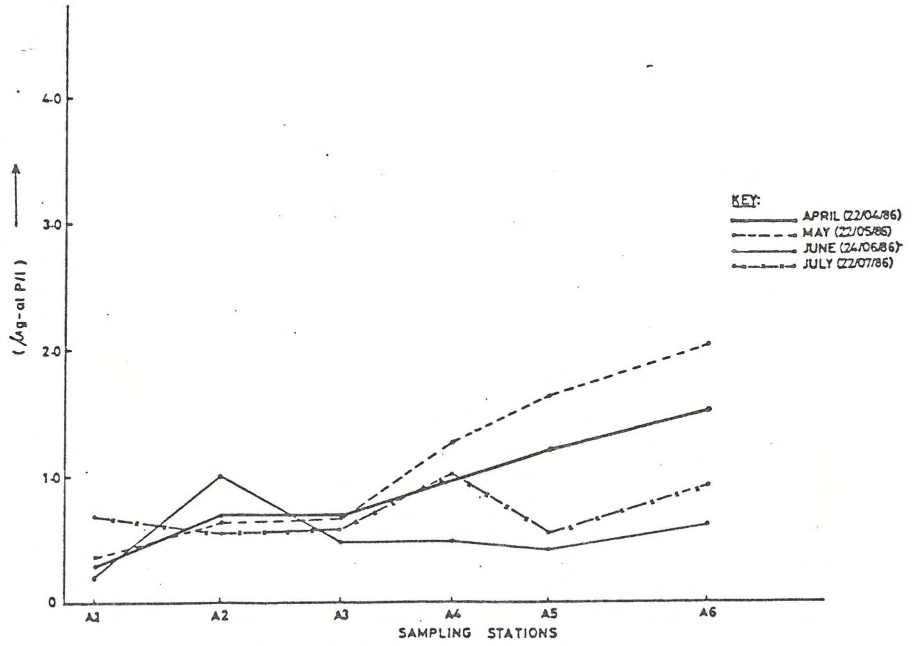

Fig. 4. Phosphate distribution patterns (April - July, 1986).

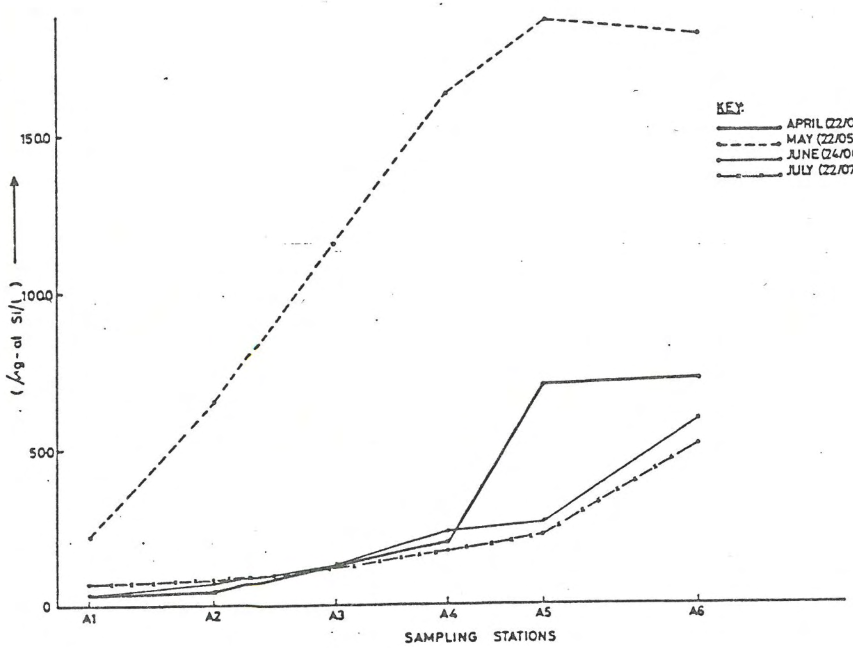

Fig. 3. Silicate distribution patterns in Tudor estuary (April - July, 1986).

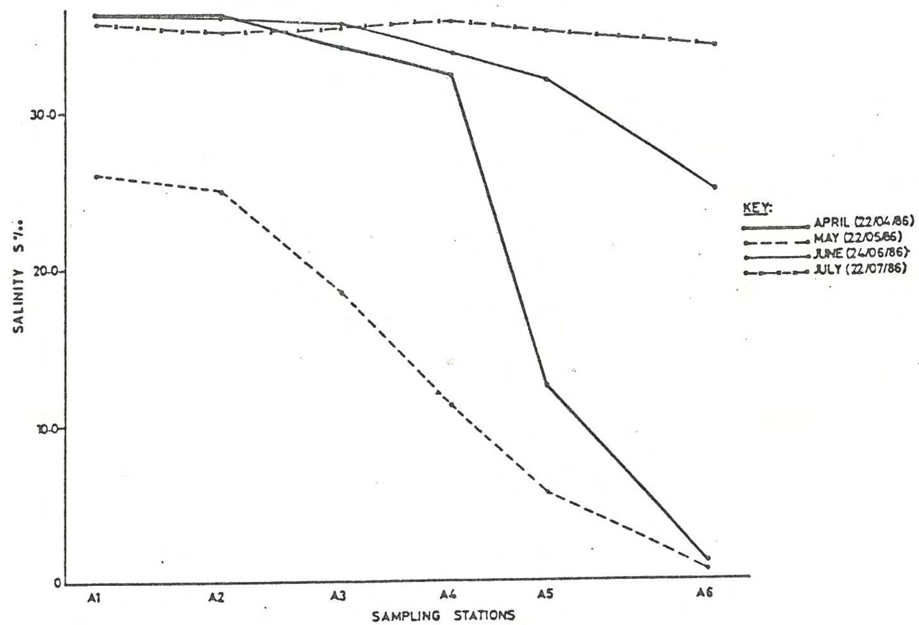

Fig. 5. Salinity profiles for Tudor estuary.

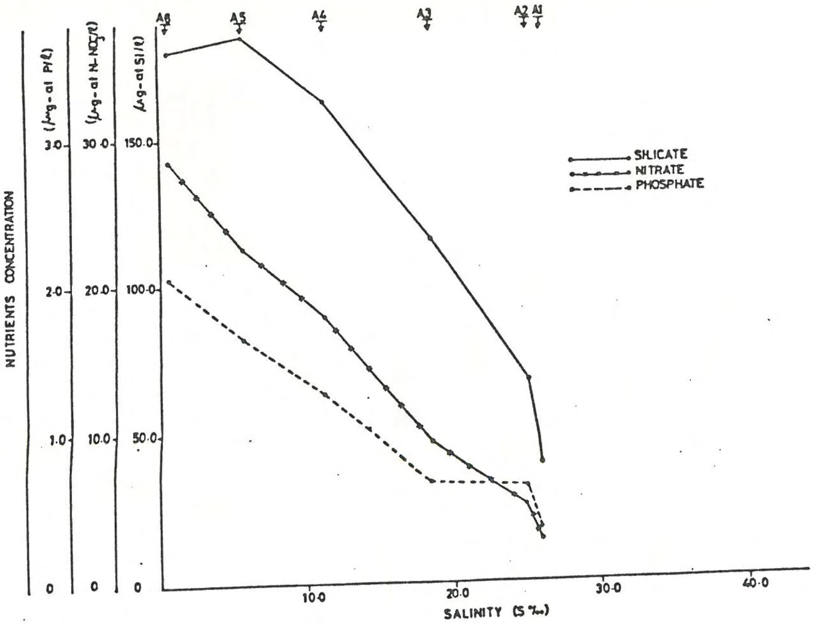

Fig. 6. Nutrients Vs. salinity profiles for the month of May in Tudor estuary.

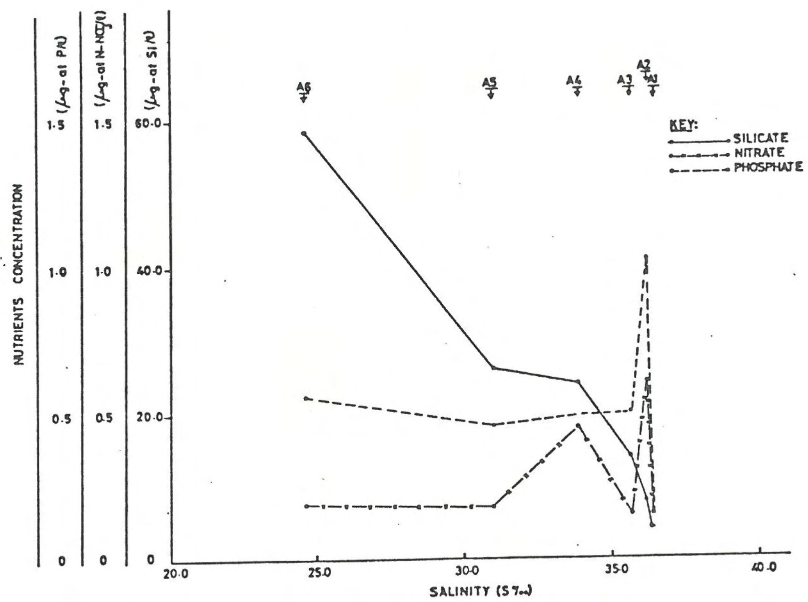

Fig. 7. Nutrients Vs. salinity profiles for June in Tudor estuary.

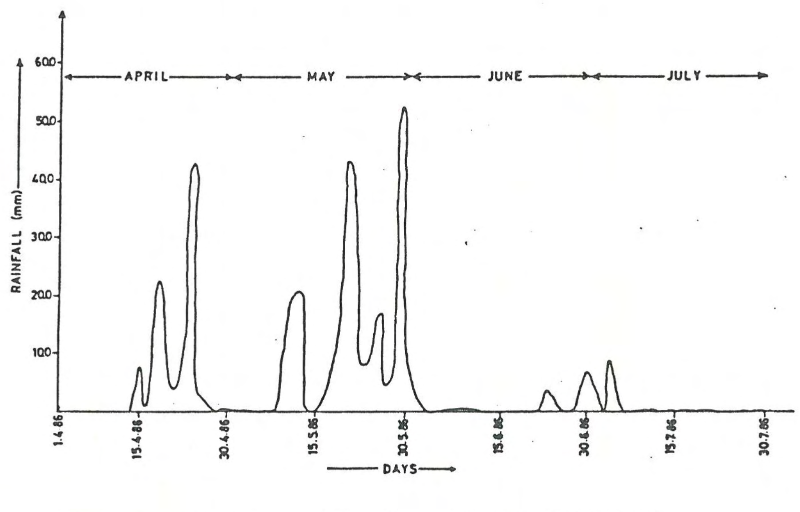

Fig. 8. Rainfall profile covering the period April to July, 1986.

3.3. ANALYSIS OF SEAWATER & SEDIMENTS AT GAZI, BAMBURI AND MALINDI TO DETERMINE THEIR CHEMICAL COMPOSITION

B. Juma

Sea water samples were collected along a 200m stretch both at 5m depth using Nansen Sampler and on the surface. These were then refrigerated and taken to the laboratory for systematic determinations for the following parameters: Dissolved oxygen, nitrite, nitrate, sulfates and PH. The work covered the months of December 1986 to April 1987.

Results at Gazi were compared to similar findings at Sabaki River Estuary and Malindi coasts (Ngomeni). Gazi maintains a constant average nitrite value for sea water of 5.3 ppm, a higher dissolved oxygen value averaging 8.0 ppm, sulfate average 1602 ppm, nitrate at 5.3 ppm. PH averages 7.3 over a constant temperature range.

Sabaki River estuary reveals lower values for dissolved oxygen and maximum nitrate content. Malindi coast averages between the two already considered stations.

Below are some results obtained:- before error corrections.

Sediment composition values are still under investigation.

Researcher: Juma,B.W.O
Date 5/5/87
Oyster Culture at Gazi, Chemical parameters

MALINDI

	Nitrite Nitrogen	Nitrate Nitrogen	P.V.	Sulphate	Temp C	PH
dec 86	4.20 ppm	4.50 ppm	2.10	6500.00 ppm	31.00	
jan 87	5.30 ppm	3.80	2.30	6725.00	31.00	
feb 87	6.90	4.20	2.30	4200.00	33.00	
mar	6.20	4.80	2.10	5500.00	32.00	
apr	4.10	4.70	2.40	5600.00	31.00	

SABAKI RIVER

	Nitrite Nitrogen	Nitrate Nitrogen	P.V.	Sulphate	Temp C	PH
dec 86	3.80 ppm	6.20 ppm	0.20	680.00 ppm	30.00	8.20
jan 87	3.70	6.10	0.10	725.00	29.00	8.30
feb 87	3.80	6.30	0.30	700.00	29.00	8.20
mar	3.90	6.20	0.20	730.00	30.00	8.40
apr	3.70	6.10	0.20	732.00	30.00	8.20

GAZI

	Nitrite Nitrogen	Nitrate Nitrogen	P.V.	Sulphate	Temp C	PH
dec 86	5.30 ppm	4.30 ppm	11.10	1600.00 ppm	32.00	7.30
jan 87	5.50	5.10	14.70	1605.00	33.00	7.60
feb 87	5.50	5.20	5.60	1600.00	33.00	7.30
mar	5.10	4.20	5.50	1602.00	31.00	7.80
apr	5.30	4.60	4.30	1602.00	32.00	7.20

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4. CORAL REEF RESEARCH

4.1. SEA URCHIN COMPETITION STUDY

N. Muthiga & T. McClanahan

Introduction

The initial experimental design intended to test sea urchin competition needed to be modified due to the difficulties of maintaining cages in the field for a long period and secondly due to the difficulty of keeping Echinometra mathaei within the cages. The new design therefore must have a shorter experimental duration and must not have to keep E. mathaei within the cages.

New Design

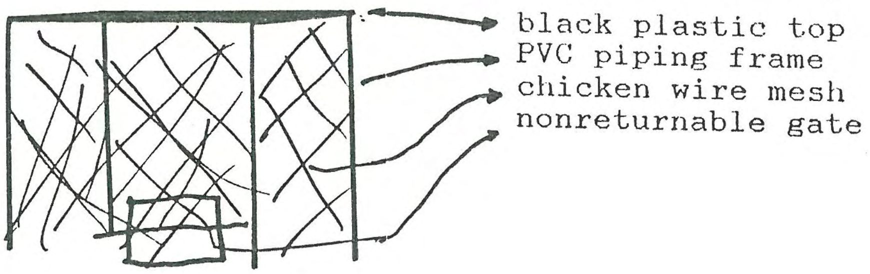
The new design is to consist of three experiments, intended to last one week each and will measure changes in sea urchin density during the one week experiment. Twelve cages will be needed per experiment. Each experiment will begin with an intial density of one species of sea urchin and the experiment will consist of adding an additional sea urchin species to 4 cages x 2 additional cages = 8 cages and having 4 control cages (total 12 cages) were no additions are made. The cages will have a nonreturnable gate which will allow species to leave the cages. The changes in the density of the species will be quantified on a daily basis for 4 days after the initiation of the experiment. The experiment will be run 3 times by starting each experiment with a new initial sea urchin species.

Experiment 1

	Day 1 Initial		Day 2 Addition	Day 3 - 5 Quantify changes indensity
Initial	species 1	x 4 cages	species 1 species 2	
	species 1	x 4 cages	species 1 species 3	
	species 1	x 4 cages	species 1 control	

Experiments 2 & 3 repeat this experiment but start with a different species.

CAGE DESIGN



PROGRESS REPORT

From December upto February the field work, data analysis and write up has been done for the paper "Predation patterns on a sea urchin <u>Echinometra mathaei</u> on Kenyan Coral reefs"(Cfr. 4.2). This work showed that predation was the single most important factor affecting <u>E. mathaei's</u> distribution and that its population expansion is due to fishing intensity. The next stage of the research work since February has focused on the competitive interactions between the three dominant sea urchins <u>Diadema setosum</u>, <u>D. savignyi</u> and <u>Echinometra mathaei</u>. Initial work consisted of attempting to develop a cage for competition experiments. This cage design was discarded after numerous attempts failed. Since April a new method has been devised which uses artificial burrows which has proved very successful. We spent 16 field days in May using this method but require an additional 30 to 40 field days to complete the study. The field work of this study will be continued in the next 2 to 4 months with an average of 10 to 15 field days per month between May and August.

4. 2 PREDATION PATTERNS ON A SEA URCHIN (ECHNOMETRA MATHAEI) ON KENYAN CORAL REEFS

T. McClanahan & N. Muthiga.

ABSTRACT

The omnivorous burrowing sea urchin Echinometra mathaei was used as a bioassay to study rates and factors affecting predation on three Kenyan coral reefs, two which were fished and a third protected from fishing. Five hypotheses concerning predation were tested; these were that predation rates should increase with 1) decreasing fishing intensity, 2) with increasing depth, 3) between sites within reefs as a function of depth, 4) with decreasing test size and that 5) E. mathaei's distribution is largely a function of predation. Results support the above hypotheses with fishing intensity being the most important variable followed by depth and lastly urchin test size. Finfish accounted for 90% of the predation, asteroids 5% and gastropods 5% which suggests that the removal of finfish is more important than shelling in restricting urchin populations. Depth was less important within fished sites than the protected site where very small differences in depth corresponded to large increases in predation. Reef flat sites consistently had the lowest predation rates which accounts for E. mathaei's natural (unfished) distribution on reef flats. Fishing pressure leads to a reduction in predators which allows E. mathaei to increase its density and expand its distribution to deeper areas. As E. mathaei is a major bioeroder on coral reefs we suggest that bioerosion is greater on fished reefs and at greater depths on fished reefs.

INTRODUCTION

Predation is often assumed to be an important force in the organization of tropical and coral reef ecosystems (Paine, 1966; Connell, 1978) but little experimental work has been completed to support this hypothesis (Sih et al., 1985). Additionally, herbivory studies have been more common (Ogden et al., 1973; Sammarco et al., 1974; Carpenter, 1981; Hay et al., 1983; Hay, 1984ab) than carnivory on coral reefs (Keller, 1983) apart from coral predation studies (Bak and van Eys, 1975; Glynn et al., 1979; Neudecker, 1979; Sammarco, 1980; Wellington, 1982). In this study we present an experimental method for measuring relative predation rates using sea urchins and test some commonly stated hypotheses concerning predation.

The primary concern of this study was to determine causes of observed sea urchin population increases in Kenyan coral reefs over time (Muthiga and McClanahan, 1987) and between reefs of differing fishing pressure (McClanahan and Muthiga, In review). As in the Caribbean (Carpenter, 1984; Hay, 1984a) and temperate areas (Estes et al., 1978; Wharton and Mann, 1981) we hypothesized that sea urchin population increases are caused by predator reductions due to overharvesting of their predators. This is a reasonable hypothesis based on changes in community structure as a function of observed and historical fishing intensity. Yet, unless experimentally tested other alternative factors which are known to affect marine invertebrate distribution such as differential recruitment (Birkeland, 1982; Ebert, 1982a), competition (Williams, 1981; Hay, 1984a; Hay and Taylor, 1985), disease (Bak et al., 1984; Lessio et al., 1984; Miller, 1985), water flow (Russo, 1977) and surf intensity (Ebert, 1982b) cannot be discounted.

Research foused on Echinometra mathaei de Blanville which is a ubiquitous benthic omnivore (Herring, 1972; Lawrence, 1975) distributed throughout the Indo-Pacific (Clark, 1976; Ebert, 1982b). E. mathaei's natural distribution is generally restricted to shallow waters (0.5 to 1.5 meters above datum in Kenya) on reef flats (Khamala, 1971), the tops of coral outcrops in reef lagoons (Russo, 1980) and back reef rocky shores (Ruwa, 1984). Yet, within heavily fished areas their distribution appears to expand into deeper reef lagoon areas (McClanahan and Muthiga, In review).

Based on previous studies and general factors believed to affect predation we tested the following 5 hypotheses. These were that 1) predation rates are lower on fished than unfished reefs, 2) predation should increase with depth, 3) predation differs between sites within reefs as a function of depth, 4) predation decreases with increasing urchin body size and based on above hypotheses that 5) Echinometra mathaei's distribution is largely a function of predator intensity.

MATERIAL AND METHODS

Three locations along Kenya's coast (south of Malindi) were choosen for their similarity in reef structure and differences in levels of fishing exploitation. These sites included the Malindi Marine National Park (MMNP) North reef which has been protected since 1968 from fishing and shelling activities, Kanamai which adjoins a residential and recreational area and Diani a highly developed tourist beach. Descriptions of these locations and Kenya's coast are included in McClanahan and Muthiga (In review), Crame (1986), Hamilton and Brakel (1984) and Khamala (1971). Briefly, all three reefs have a seaward reef edge (RE) exposed to waves during most tides, a reef flat (RF) exposed during neap and all spring tides and a shallow reef lagoon (RL). Tides in Kenya have a 4 m tidal range and a 3.2 mean spring tide range (Brakel, 1980).

Predation was studied by a bioassay technique which restricted Echinometra mathaei to nylon transect lines using a tagging method modified from Ebert (1965). Nine to eleven urchins were perforated with a hypodermic needle, threaded with monofilament line and tied to transect lines at 2 m intervals. Within each location 3 transect lines were laid perpendicular to shore at each of the reef edge, reef flat, and reef lagoon sites (Table 1). Reef flat urchins were placed in shallow (< 0.5 m) pools to avoid dessication stress. This procedure was repeated twice at each location between September and December, 1986 during spring tides except at MMNP reef edge where 9 transect lines were laid only once. The test width of each urchin was measured with calipers to the nearest millimeter and depth was calculated in relation to datum using published tide tables (Kenya Ports

Authority, 1986). Transects were visited every 24 hours for a 3 day period. The following categories were used to determine predator types; 1) missing and broken tests indicated predation by finfish, 2) tests with a single perforation in the test, periproct or peristome indicated predation by a gastropod probably Cypraecassis rufa Linne (bullmouth helmut shell) and 3) an intact bleached test missing spines indicated predation by an asteroid probably Culcita schmideliana Retzius (pin-cushion star). During the first sampling interval only the day on which predation occured was recorded, while during the second sampling interval both the day and predator type were recorded. Transect lines removed by fishermen and deaths due to undetermined causes were removed from the data analysis.

In the data analysis the average survival rate was calculated for each transect, site and location. ANOVA was used to test for differences in survival within and between transects and reefs. Survival rates were correlated with Echinometra mathaei densities collected from McClanahan and Muthiga (In review). Additionally, survival rates were correlated with depth in relation to datum and test size.

RESULTS

Survival rates within the three locations and sites (Table 2) show highly significant differences for most comparisons. The MMNP had the highest predation rate which can almoost exclusively be attribute to finfish (Table 3). Observations suggest that ballistads were the most important predators with Balistapus undulatus Mungo Park (red-lined tiggerfish) being most prominent in the reef lagoon, Rhinecanthus aculeatus Linne (Picasso triggerfish) on the lagoonal edge of the reef flat and Rinecanthus rectangulus Schneider (wedge-tailed triggerfish) on the seaward reef flat and reef edge. Predation on the MMNP reef edge and reef lagoon were similiarily high with the lowest rate on the reef flat. Site differeces can be attributed to depth (Fig. 1a and Table 4) as small increases in depth corresponded to increases in predation.

Kanamai and Diani (fished areas) had lower predation rates than MMNP within all three sites. Predation within reef edge and reef flats were similiar in Kanamai and Diani but reef lagoons differed with predation being lowest within the Diani reef lagoon and subsequently the whole reef. Predation in relation to depth, although significant in Diani (Table 4) was less important than in the MMNP. Most urchins (79%) survived the duration of the experiment within Diani's reef lagoon. Predation was also largely due to finfish within fished sites but there is an increase in the relative importance of invertebrate predators which can probably be attributed to the gastropod Cypraecassis rufa and the asteroid Culcita schmideliana which were observed predating on experimental sea urchins. Observations on finfish abundance suggest that species from Ostracoidei may have been equally or more important predators than Ballistoidei in fished reefs especially in Diani's reef lagoon.

Variability within sites (Table 5) suggests that differences in transect placement within sites and times were often significant and predation appeared to be patchy. Reef edges appeared to be most variable followed by reef flats and reef lagoons. Differences within sites were not as great as differences between sites and locations. Unquantified variables that appeared to affect predation were that predation appeared lower if individuals were able to find crevices, in seagrass beds compared to coral outcrop areas and in areas with greater surf activity.

The relationship between test size and survival, although significant for some sites, locations and totals, appears to be the least important of the measured variables (Table 4). Test size appears to be most important within reef lagoons. Finally, predation rates within study sites appears to be a good predictor of *Echinometra mathaei* densities regardless of sites or locations (Fig. 2).

Some complicating factors must be considered due to variations in sampling between reefs. First, although we suggest that differences between MMNP and fished reefs are due to fishing activities the MMNP aggregate sampling was at a greater depth (Table 1) than fished reefs which could account for differences. Yet, the MMNP reef flat data collected at a height of 0.6 m above datum had a survival rate of 0.95 ± 0.12 days (n = 60) which is considerably lower than any site within fished reefs regardless of depth. A second compounding factor is that, despite random sampling, test sizes were slightly smaller in MMNP than in fished sites. Nevertheless, this is unlikely to affect results greatly as predation was so rapid in MMNP (78% eaten in 24 hours) that 2.0 to 5.5 mm differences in average test size are unlikely to explain differences. The high positive correlation between test size and survival for the total study (Table 4) may contribute, in part, to differences in sites rather than test sizes.

DISCUSSION

The method appears to be useful for testing hypotheses about predation and data is supportive of stated hypotheses. The tagging technique as concluded by Ebert (1965) appears to have little detrimental effect on urchins as suggested by the high urchin survival rates in the Diani reef lagoon. Deaths due to undetermined causes were highest on reef flats and edges which suggests that physical factors such as surf intensity on the reef edge and water temperature and salinity fluctuations on the reef flat may be the causes of mortality. It should also be appreciated that mortality rates are relative and should not be confused with natural rates for reasons that handling, transporting, perforating the test and restricting movement should result in their weakening and attracting predators. They should be easier to prey on than undisturbed urchins and should therefore be a good measure of predator abundance.

An added benefit of the method is the ability to determine general predator types. Most tests were missing which, although presumed to be predated on by fish, is largely based on our observations on fish feeding behavior. Invertebrates do not feed as aggresively as finfish nor do they break urchin tests. Yet, there is the possibility that finfish removed tests previously fed on by invertebrates but the procedure of checking tests every

24 hours should have reduced the liklihood of this error.

The most prominent difference in predation rates is the difference between protected and fished sites. We attribute this difference to predator removal within fished areas. Fishermen catch a variety of edible finfish which feed on urchins. As well, the gastropod Cypraecassis rufa is collected and sold for its ornamental value. Results suggest that fishing rather than shelling is more important in controlling sea urchin predation rates and population increases. Triggerfish, which may be the most important sea urchin predators, although claimed to be poisonous (Smith, 1965; Carcasson, 1977), are commonly eaten in Kenya once their poisonous skins are removed (McClanahan, personal observation). Species from the Ostracoidei and the asteroid Culcita schmideliana are probably the least harvested predators (although some Ostracoidei are dryed and sold as ornaments) and may therefore be most important on overfished reefs. The reason that unharvested species have not responded to restrict urchin population increases remains obscure but there may be other limitations on their population expansions, feeding rates and prey preference. Differences within reefs may also be attributed to fishing pressure. Lagoons showed the greatest variation and may be more susceptible to overfishing due to their closeness to shore and calm conditions in comparison to reef edge sites.

Echinometra mathaei's natural (unfished) distribution limits it to locations between 0.5 and 1.5 m above datum (Ruwa, 1984). The upper limit is presumably due to dessication but the lower limit appears due to predation. E. mathaei is probably not free from predation at any height but predation intensity increases with depth due to a greater diversity and abundance of predators in deeper waters. Within the MMNP very slight changes in reef height effect predation but in fished reefs the distinction is less important as competition for urchins may not be as intense due to predator reductions. Negative geotrophism in E. mathaei and other sea urchins (Binyon, 1972) may be a predator avoidance strategy.

This system has similiarities with the Pisaster-Mytilus interactions of the north-western United States (Paine, 1974) but the predator guild on the coral reef is more diverse and factors affecting them less understood. Cypraecassis rufa can predate on Echinometra mathaei at the highest reef levels including the reef flat. We also observed the ballistads Rhinecanthus aculeatus and Rhinecanthus rectangulus living in cracks and urchin burrows on the reef flat during low tides at heights not greater than 1 m above datum but usually less than 0.5 m above datum. Below mean low water spring (0.3 m above datum) the predator guild diversity increases further to include species from Ostracoidei, other Ballistoidei, Scaridae, Asteroidea and others. We therefore suggest that a keystone guild concept rather than the keystone species concept (Paine, 1966) may be more appropriate in this system. Predation seems to be the single most important factor controlling E. mathaei's distribution within the locations studied. Further experimental work needs to be completed on other species and taxonomic groups before confirming generalizations about the importance of predation and carnivory in coral reefs and tropical ecosystems.

If the keystone concept is consistent than Echinometra mathaei should be the top competitor in the absence of predators. Since E. mathaei expands its distribution proportional to a decrease in predation and since it is a benthic omnivore this concept seems consistent. Yet, fishing removes potential competitors (Hay, 1984a; Hay and Taylor, 1985) as well as predators and therefore this hypothesis remains untested although Hay and Taylor's (1985) study suggests that sea urchins may be better competitors than finfish in the absence of predation.

The increasing size of an individual has been suggested as a form of predatory escape for marine invertebrates (Connell, 1972; Vermeij, 1972) and results are consistent with this observation. Smaller individuals are more susceptible to predation from a larger number of species and individuals and therefore survival increases with size. Models based on constant mortality for sea urchins and other intertidal invertebrates (Ebert, 1973; Ebert, 1981) may be unrealistic. Additionally, changes in body size between closely related species may be a predator escape adaptation over evolutionary time.

Fishing has a major effect on coral reef community structure and as recognized by Hay (1984a) community organization cannot be seen independently of fishing intensity. Additionally, Echinometra mathaei is a major bioeroder of coral reefs (Russo, 1980; Hutchings, 1986) and therefore bioerosion may be proportional to fishing intensity. We therefore suggest that ecosystem functions such as coastal protection cannot be seen independently of human exploitation.

ACKNOWLEDGEMENTS

Funding was provided by WWF, IUCN and the Kenyan-Belgian Project in Marine Ecology. Research clearance was granted by the Kenyan Office of the President, assistance was also provided by the Kenya Marine and Fisheries Research Institute, J. Nzau assisted with the field work.

Table 1. Averages and ranges of the sample heights in relation to datum, sea urchin test lengths and total sea urchin and transect sample sizes on reef edges (RE), reef flats (RF) and reef lagoons (RL) at the three locations.

Location	Malindi (Unfished)				Kanamai (Fished)				Diani (Fished)			
Site	RE	RF	RL	Total	RE	RF	RL	Total	RE	RF	RL	Total
Height, m	-1.5	0.6	-1.17	-0.81	-0.16	0.97	1.06	0.56	-0.32	0.3	0.07	0.05
Range, m	4.0	0.2	2.3	4.3	1.8	0.5	0.3	3.7	0.8	0.9	0.7	1.5
Size, mm	34.9	34.8	35.5	35.0	36.3	38.6	38.5	37.7	40.0	40.4	40.8	40.5
Range, mm	24.0	19.0	17.0	26.0	17.0	29.0	22.0	32.0	17.0	21.0	35.0	35.0
Total n	93	60	58	211	58	43	50	151	34	47	58	139
Transect n	9	6	6	21	6	4	4	14	4	4	5	13

Table 2. Survival rate in days for a three day period within the three locations, sites and totals. ANOVA test of significance between sites and locations. Variation is measured as one standard error. NS = not significant, * = $p < 0.05$, ** = $p < 0.01$ and *** = $p < 0.001$.

	Reef Edge	Reef Flat	Reef Lagoon	Totals	ANOVA, F
Malindi	0.13 ± 0.04	0.95 ± 0.12	0.09 ± 0.06	0.35 ± 0.05	41.4 ***
Kanamai	1.40 ± 0.17	1.84 ± 0.20	1.78 ± 0.20	1.64 ± 0.11	1.7 NS
Diani	1.12 ± 0.23	1.83 ± 0.20	2.41 ± 0.15	1.90 ± 0.11	11.2 ***
Totals	0.71 ± 0.08	1.48 ± 0.10	1.41 ± 0.11	1.17 ± 0.06	19.2 ***
ANOVA, F	35.3 ***	9.9 ***	72.7 ***	98.1 ***	

Table 3. Mortality and predator types determined by test condition for the three sites, locations and totals. Missing tests are assumed to be predated on by fish. Undetermined causes are deaths occuring by means other than predation. Numbers in parentheses are percentages, the undetermined and total eaten categories are percentages of the total sample size. All other classifications are percentages of the total eaten category. See table 1 for notation.

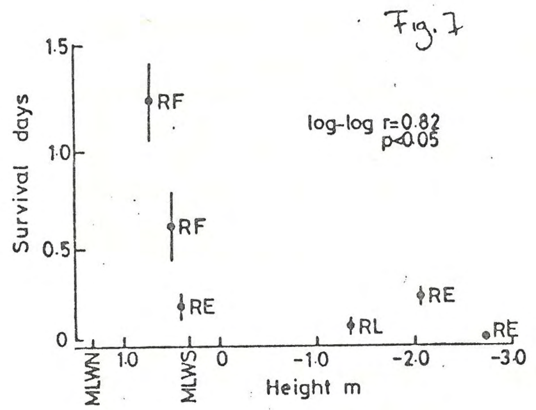
	Malindi				Kanamai				Diani				Site Total			
	RE	RF	RL	Total	RE	RF	RL	Total	RE	RF	RL	Total	RE	RF	RL	Total
Sample size	103	30	30	163	29	30	30	89	29	31	28	88	161	91	88	340
Undetermined	0 (0)	1 (3.3)	0 (0)	1 (0.6)	0 (0)	6 (20)	0 (0)	6 (6.7)	5 (17.2)	3 (9.7)	0 (0)	8 (9.1)	5 (3.1)	10 (11)	0 (0)	15 (4.5)
Total Eaten	103 (100)	29 (96.7)	30 (100)	162 (99.4)	15 (52)	11 (36.7)	16 (53.3)	42 (47.2)	22 (75.9)	18 (58.1)	11 (39.3)	51 (58.0)	140 (87.0)	58 (63.7)	57 (64.8)	255 (75.0)
Missing Test	103 (100)	26 (89.7)	30 (100)	159 (98.1)	10 (66.7)	2 (18.2)	4 (25.0)	16 (38.1)	7 (31.8)	15 (83.3)	10 (90.9)	32 (62.7)	120 (85.7)	43 (74.1)	44 (77.2)	207 (81.2)
Observed Fish	0 (0)	1 (3.4)	0 (0)	1 (0.6)	4 (27.7)	2 (18.2)	7 (43.8)	13 (31.0)	8 (36.4)	2 (11.1)	0 (0)	10 (19.6)	12 (8.6)	5 (8.6)	7 (12.3)	24 (9.4)
Total Fish	103 (100)	27 (93.1)	30 (100)	160 (98.8)	14 (93.3)	4 (36.4)	11 (68.8)	29 (69.0)	15 (68.2)	17 (94.4)	10 (90.9)	42 (82.4)	132 (94.3)	48 (82.8)	51 (89.5)	231 (90.6)
Gastropoda	0 (0)	0 (0)	0 (0)	0 (0)	1 (6.7)	7 (63.6)	1 (0)	9 (21.4)	3 (13.6)	0 (0)	0 (0)	3 (5.9)	4 (2.9)	7 (12.1)	1 (1.8)	12 (4.7)
Asteroidea	0 (0)	2 (6.9)	0 (0)	2 (1.2)	0 (0)	0 (0)	4 (25.0)	4 (9.5)	4 (8.3)	1 (5.6)	1 (9.0)	6 (11.8)	4 (2.9)	3 (5.2)	5 (8.8)	12 (4.7)
Total Invert.	0 (0)	2 (6.9)	0 (0)	2 (1.2)	1 (6.7)	7 (63.6)	5 (31.3)	13 (30.9)	7 (31.8)	1 (5.6)	1 (9.0)	9 (17.6)	8 (5.7)	10 (17.2)	6 (10.5)	24 (9.4)

Table 4. F- values and levels of significance for correlations between survival and height in relation to datum and urchin test size for the 3 sites and totals. All significant correlations are positive. See Tables 1 and 2 for notation.

	Malindi				Kanamai				Diani				Site Total			
	RE	RF	RL	Total	RE	RF	RL	Total	RE	RF	RL	Total	RE	RF	RL	Total
Height	1.95	0.00	0.02	39.5	0.50	0.42	0.00	2.18	0.12	4.5	1.40	9.36	17.8	2.37	53.3	95.6
	NS	NS	NS	***	NS	NS	NS	NS	NS	*	NS	**	***	NS	***	***
Test Size	0.15	0.62	2.09	0.66	0.64	0.53	8.32	9.68	3.16	0.18	4.12	4.17	12.8	5.94	47.9	72.4
	NS	NS	NS	NS	NS	NS	**	***	NS	NS	*	*	***	*	***	***

Table 5. Comparison of survival between transects within sites. F- values and level of significance are presented. NS = not significant, * = $p < 0.05$, ** = $p < 0.01$ and *** = $p < 0.001$.

	Reef Edge	Reef Flat	Reef Lagoon
Malindi	3.3 **	2.8 *	0.7 NS
Kanamai	3.5 **	1.4 NS	0.5 NS
Diani	18.9 ***	3.9 **	5.3 ***



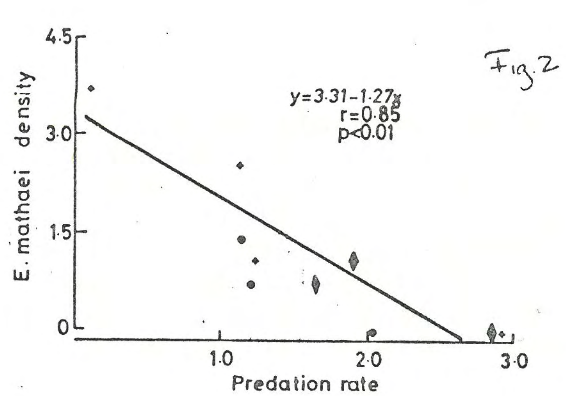


Figure Legends:

Fig. 1. Predation rates as a function of depth in relation to datum within the Malindi Marine National Park for all sites within the reef flat (RF), reef edge (RE) and reef lagoon (RL). Bars represent one standard error. MLWN = mean low water neap and MLWS = mean low water spring.

Fig. 2. The density of <u>Echinometra mathaei</u> as a function of predation rates calculated as the total length of the experiment (3 days) - survival (days). Locations within the reefs are symbolizied as + - *reef lagoon*, ● - *reef flat* and ◆ - *reef edge*.

MACROFAUNAL COMPOSITION AND ZONATION ON SANDY BEACHES AT GAZI, KANAMAI AND MALINDI BAY KENYA

R.K. Ruwa,

ABSTRACT

Based on the most conspicuous macrofauna which are the crabs, there are three biological zones on the sandy beaches. In a downward shore direction these are: *Ocypode* zone, *Dotilla* zone and *Uca-Macrophthalmus* zone. These zones are related to tidal level, watertable and texture of sediment. The *Ocypode* zone extends from around MHWN to even above EHWS. The sediments at the *Ocypode* zone are loose coarse sand but sometimes firm calcereous sand between MHWS and MHWN. The zone has many burrows of mixed sizes and there are three *Ocypode* species which burrow here namely, *O. ceratophthalmus*, *O. ryderi* and *O. cordimanus*. These species hardly co-occur and the burrows at any particular portion of beach belong to a single species of the *Ocypode*.

The *Dotilla* zone extends between MTL and slightly below MHWN. The texture of the substrate is fine sand. The species occupying this is almost exclusively the *Dotilla fenestrata*. However, samples of sand collected from the edges of the ebbing and flooding tides were sieved and two species of crabs *Hippa adactyla* and *Emerita austroafricana* were seen. The position of the watertable where *Dotilla fenestrata* was found was 10-20cm from the surface. They were not found where seepage occurred even though the levels were optimal for them.

Slightly below MTL to MLWS, the watertable is usually at the surface and seepage occurs conspicuously. The substrate is muddy sand with small stones. This is the *Uca-Macrophthalmus* zone. The *Uca* species were *Uca vocans* and *Uca tetragonon*. The *Macrophthalmus* species were *M. grandidieri* and *M. parvimanus* which were the most common and the less common ones were *M. milloti* and *M. bosci*. There were 3 species of portunid crabs in the brackish water pools and 8 species of gastropods in the muddy sand. In the silty muddy sand of Malindi beach *Echinodiscus bisperforatus* was found in large numbers. This is the northern-most occurrence of this species in the Western Indian Ocean.

The present results were compared with those of other parts of the Western Indian Ocean and the significance of their similarities and differences is discussed.

INTRODUCTION

There are some published works on the ecological distribution of the invertebrate macrofauna of sandy beaches in the Western Indian Ocean, e.g. at the coast of Somalia by Vannini (1976, 1980); coast of Tanzania by Hartnoll (1973,1975); coast of Seychelles by Taylor (1968); Aldabra Atoll by Taylor (1971 a); coasts of Madagascar by Crosnier (1962,1965). There are also similar published works done on the coast of Southern Africa which has a tropical faunal component because of the influence of the Mozambique current on that coast (Newell 1957). The ecological studies of the sandy beaches on the coast of Mozambique were studied by Macnae and Kalk (1962); whereas those of the coast of Natal Province in South Africa were studied at Kosi bay by Broekhuysen and Taylor (1959), Richards bay by Millard and Harrison (1953) and Durban bay by Day and Morgans (1956).

The only published studies on zonation of macrofauna of the sandy beaches on the Kenya Coast by Jones (1972) and Icely and Jones (1978) were confined to some species of Uca and two species of Ocypode. The following study was therefore done to provide some detailed information by including several species whose taxonomy is well known so that their distribution can also be compared with others in the earlier mentioned tropical environments. The list of the species whose distributions were described in this study is shown in table 1.

STUDY AREA AND METHODS

The studies were carried out at Gazi, Kanamai and Malindi Bay (figure 1) from April 1986 to December 1986.The Gazi beach is in Gazi Bay which is sheltered from heavy wave action. It receives seasonal river input of freshwater and permanent inflow of underground water which seeps to the seashore (Ruwa and Polk, In press). The watertable oscillates considerably on this beach. The Kanamai beach receives permanent inflow of underground water which seeps to the beach (Ruwa and Polk, in press). The watertable does not considerably oscillate. This beach is about 0.75km to the living reef edge. It is therefore fairly sheltered from heavy wave action. The third locality, Malindi beach is situated in the Malindi Bay which receives inflow from the permanent River Sabaki. The latter carries lots of land based sediments which are deposited in the bay. The seawater in this bay is permanently brown due to silt suspension.
Around Vasco da Gama pillar, the terrestrially based sediment deposits from the river are shallow and the rock platform is visible. There is underground water seeping through the rock platform and where there are stabilized sediments an estuarine beach environment is created.
The zonation accross the beach was studied using the quadrat - transect method and their distribution was related to height of shore, substrate and seepage of underground water to the seashore. The part of the seashore considered as the sandy beach constituted the deposits of sediments of the higher shore levels around the extreme high water spring to the beginning of the marine phanerogram beds on the lower shore.

Transects of width of 2m were sampled accross the beach by making counts of the cryptic or burrowed macrofauna occurring within 2 x 2m quadrats placed consecutively along the transect. Burrows were dug using a shovel and the sediments sieved when necessary in order to discern the types of macrofauna occupying such niches and therefore ascertain the zones of various macrofauna accross the shore. For some transects, counts of crab holes were made and the sizes of the mouths of the crab holes were measured using calipers before digging some of the burrows. Data on the counts of the burrows were used in constructing kite diagrams.

Lines rather than kite diagrams were used to illustrate the distribution of various macrofauna which are highly motile e.g. the crabs and for macrofauna which were either found in small numbers or within narrow horizontal distributions on the beach. The substrate was qualitatively described as coarse sand, calcereous sand, fine silted sand , muddy, sandy-mud and muddy sand. The profiles of the transects were determined by the levelling method described by Southwood (1965) and Day (1974).

The shore elevation were calibrated with respect to the Kilindini datum from several observations made when the sea was calm around neap tide days using the Kenya Ports Authority (1986) tide tables. The heights of the conventional levels of tides as calculated by Brakel (1982) were adopted. The values of these are: Extreme high water spring (EHWS), 4.0m; mean high water spring (MHWS), 3.5.m; mean high water neap (MHWN), 2.4m; mean tide level (MTL), 1.9m, mean low water neap (MLWN), 1.4m; mean low water spring (MLWS), 0.3m.
The identifications of the macrofauna were done using the taxonomic literature of Barnard (1960), Barnes (1970), Crosnier (1962,1965), Clark and Rowe (1971), Day (1974), Oliver (1981), Richards (1984) and Serene (1973).

RESULTS

Accross the sandy beaches, there was a consistent tendency that the higher shore level above MHWN was characteristically made up of predominantly coarse sand substrate at all the localities (figure 2 to 6). The burrowing macrofauna in this habitat were Ocypode spp, namely O. ceratophthalmus at Gazi and Malindi and O. cordimanus at Kanamai (Table 2).
In the middle shore levels of the sandy beach the quality of the substrate was variable. Between MTL and MHWN the substrate could be fine silted sand or sandy mud. Where the watertable was low the substrate was moistened or wet as in the sandy mud habitats. The macrofaunal composition was as follows:
Dotilla fenestrata occupied fine sand habitat (figure 3,4 and 5) lying 10-20cm above the watertable but in sandy mud habitats on mangrove peat(figure 2) where the water table was at the surface Uca lactea occupied such habitats (Table 2).

In the lower shore levels the nature of the substrate between MTL and MLWN was similar to that between MLWN and MLWS (figure 2 to 6). The substrate could be wet fine silted sand or muddy sand. The wetness was due to the watertable being close or at the surface. Water seeping from the surface could form puddles or small pools. The Thalamita spp and Scylla serrata were found in these pools. The muddy sand substrate supported the highest number of species of macrofauna at Gazi and Kanamai beaches (Table 3). Comparisons of the macrofaunal compositions of the three beaches showed that Gazi and Kanamai beaches had more numbers of species and also more numbers of commonly occurring species between them than with the Malindi Bay beach.

Except for the Ocypode spp which wandered away from their burrows the rest of the species of crabs move about only around or close to their burrows. Both Ocypode ceratophthalmus and O. cordimanus were frequently encountered at the lower shore at low tide but when pursued they rapidly escaped to the higher shore levels into their open burrows. In a few cases O. ceratophthalmus decided to burrow (or rather bury) themselves in the muddy sand or sandy mud at the lower levels when pursued rather than escape to their open burrows at the higher shore levels.

The data on sizes of the mouths of burrows (figure 4) could not indicate segregation of the crabs by size even for singly occurring species in particular zones. However, the density of the crab holes (figure 4 and 5) helped to indicate the intensiity of sediment perturbations accross the sandy beaches due to the burrowing activities.

DISCUSSION

Faunal Compositions

Despite the differences in hydrological sources of freshwater flowing to the seashore at Gazi and Kanamai, their faunal compositions (Table 3) are similar in terms of having common species and species diversity. On the other hand comparison of Gazi and Malindi beach faunal compostion show that the latter has low species diversity and that most of the species encountered also occur at Gazi beach. The poor species diversity may be due siltation resulting from silt carried by the permanent River Sabaki which is deposited on the Malindi beaches. It is noteworthy to mention that the occurrence of Echinodiscus bisperforatus at Malindi is of significance in two ways. First, it is the northernmost occurrence in the Western Indian ocean and on the coasts of the islands, it was recorded at the coast of Madagascar by Pichon (1966). However, according to Clark and Rowe (1971) this species has also been recorded in the Red Sea. Secondly, it occurred in similar muddy sand habitats in estuarine environment in all the geographical areas mentioned.

The conspicuous occurrence of some species in some beaches but lacking at others may partly be due to disimilarities in the microenvironments of the habitats and behavioural differences. For example, the presence of large numbers of Uca lactea on Gazi beach but lacking at Kanamai may be due to the presence of mangrove peat at the Gazi beach which makes the microenvironment mangrove like biotope. Uca lactea was similarly found on a beach created on mangrove peat after removal of mangrove trees. Typically Uca lactea is mangrove-associated fiddler crab (Hartnoll 1975).

Uca tetragonon and Dotilla fenestrata which occur at Kanamai and Malindilacked at Gazi beach. The lack of Dotilla fenestrata may be due to the presence of shallow sediment on peat which remained wet throughout the low tide around spring tide days. Hartnoll (1973, 1975) records that Dotilla fenestrata burrows in well drained sand and does not occur in waterlogged substrates.

It is difficult to explain the lack of Uca tetragonon at Gazi and Malindi bay beaches. Uca tetragonon occurs in large numbers with Uca vocans at Kanamai beach but at Gazi and Malindi beaches where Uca vocans similarly occurs, Uca tetragonon was lacking. At all the localities where these Uca spp were seen, there were small stones or coral rubble in the muddy sand substrate. Thus since at Kanamai both species occupied muddy sand with small stones or coral rubble, it would have been expected that Uca tetragonon is also seen at Gazi and Malindi sites because the habitats were similar. At Aldabra Atoll Taylor (1971 a) observed that Uca tetragonon occurred at this Atoll but Uca vocans lacked. This suggests that there may be ecological differences in their niche requirements so that they only co-occur when such requirements for both species are provided for in the biotope. If the biotope offers requirements which suit one of the species then they do not co-occur. Indeed, when the work of Icely and Jones (1978) is consulted the question becomes more complicated because they found out that (i) the two species showed similar preferences for open shore; (ii) there was little difference in the particle size and organic content of the substrate they occupied and finally (iii) their feeding structures showed only minor differences hence they could sample similar texture of sediments.

The distribution of the Ocypode species at various localities may be dictated by behavioural differences. At each sampling site, in Malindi Bay, Kanamai and Gazi, only a single species of Ocypode was encountered. One would therefore wonder whether not more than one species can occupy same area of a beach. On some Kenyan beaches Jones (1972) recorded similar observations in their studies on O. ceratophthalmus and O. ryderi. In their transects they found out that at each locality the burrows were occupied by one of the species only. Night catches of the Ocypode crabs at different localities during low tide when they are found in large numbers showed that 98 - 100% of the crabs caught at each locality belonged to either one of the two species.

This observation is not confined to Kenyan beaches only. Elsewhere, Ocypode ryderi and O. ceratophthalmus wherever they were found together in a beach, only one of them was abundant as observed at Inhaca, Mozambique by Macnae and Kalk (1962); Durban Bay, South Africa by Day and Morgans (1956) and Richards Bay South Africa by Millard and Harrison (1953). At the beach of Sar Uanle dune, Somalia Vannini (1976) observed that in a mixed catch of O. cordimanus and O.ryderi only 7.4% were O. cordimanus and O. ceratophthalmus occurred at different parts of the sandy beaches. At Mahe Seychelles Taylor (1968) found that O. ceratophthalmus occurred in higher numbers than O. cordimanus. The reasons for such disparities could be due to differences in aggresiveness but there is no conclusive evidence yet.

Zoogeography

The faunal distribution of the various species shown in Table 4 contributes to the evidence that many species in the Western Indian Ocean are found in several geographical areas in this region (Taylor 1971b). It is necessary to point out that this study in Kenya was done when presently the taxonomy of tropical invertebrates is better known than at the earlier times when such similar studies were carried out elsewhere in the Western Indian Ocean. The impression that may therefore misleadingly portray that the Kenyan coast sandy beaches have the highest species diversity should not be overlooked.

Zonation

Using the crabs which are the most conspicuous sandy beach macrofauna, there are three biological zones based on their distribution. In a downward shore direction these three characteristic zones accross the beach are easily distinguished and are namely :*Ocypode* zone; *Dotilla* zone and *Uca* - *Macrophthalmus* zone.

The *Ocypode* zone is mainly composed of coarse sand substrate. Three species of *Ocypode* burrow in this zone. These are : *O. ceratophthalmus*, *O. cordimanus* and *O. ryderi*. Characteristically they stay in their burrows at high tide but at low tide they wander about making feeding excursions on the entire beach and especially so during night low tide (Vannini 1980 , Icely and Jones 1972, Hughes 1966). Thus their zone of distribution accross the shore widens at low tide.

The substrate in the *Dotilla* zone is mainly fine to medium grain sized sand (Hartnoll 1973). The watertable in this zone is near the surface e.g 10-20 cm below the surface as recorded in the present Kenyan study; 10 - 15 cm below the surface as recorded at Inhaca Island, Mozambique by Macnae and Kalk (1962).

At the lower end of the beach between MTL and MLWS the watertable is at the surface and the substrate is muddy sand. This portion of the shore experiencing seepage is the *Uca* - *Macrophthalmus* zone. Seepage is a common hydrological process in the Western Indian Ocean e.g at the Somali coast (Chelazzi and Vannini 1980); coast of Kenya (Ruwa and Polk In Press); coast of Tanzania (Hartnoll 1973); Inhaca Island, Mozambique (Macnae and Kalk 1962); Seychelles (Taylor 1968); Aldabra Atoll (Taylor 1971 a) and Madagascar (Pichon 1966). The presence of several same species of macrofauna where seepage occurs (Table 4) adds an interest to the search and understanding of the environment in this region.

The *Dotilla* and *Uca* - *Macrophthalmus* zones are profoundly influenced by the watertable. Lanyon et al (1982) stated that changes in wave regime, shelf-wave activity, tidal fluctuation or mean sea-level variation cause the watertable continually to change position and alter the proportion of beach which is either saturated or unsaturated. This may also partly explain local differences in the species composition at different beaches.

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Table 1. List of species of macrofauna encountered in this study. The species marked with asterisks were found outside the transects. According to Vannini's (1976) review, the species once referred to as *O. kuhli* in this region is distinctly *O. ryderi*. The latter species was collected at Gazi whereas the *Hippa* and *Emerita* spp were collected at Kanamai.

Family	Species
Ocypodidae	*Ocypode ceratophthalmus* Pallas
	O. cordimanus Desmarest
	**O. ryderi* Kingsley
	Uca lactea de Haan
	U. vocans Linnaeus
	U. tetragonon (Herbst)
	Dotilla fenestrate Hilgendorf
	Macrophthalmus grandidieri A. Milne Edwards
	M. parvimanus Guverin
	M. milloti Crosnier
	M. bosci Audouin & Savigny
Portunidae	*Thalamita crenata* (Latreille)
	T gatavakensis Nobili
	Scylla serrata (Forskal) - juveniles
Hippidae	**Hippa adactyla* Fabreille
	**Emerita austroafricana* Schmitt
Naticidae	*Natica gualtierana* (Petit)
	Polinices mammila (Linnaeus)
Nassaridae	*Nassarius arcularius* (Linnaeus)
	N. coronatus (Bruguire)
	N. fenwicki Kilburn
	N. margaritifera (Dunker)
Strombidae	*Strombus mutabilis* Swainson
	S. gibberulus Linnaeus
Neritidae	*Nerita polita* Linnaeus
Scutellidae	*Echinodiscus bisperforatus* Leske

Table 2. Distribution of various species in the higher level of the sandy beaches at Gazi, Kanamai and Malindi. The letter (P) indicates where the organism was seen and recorded.

Species	Gazi		Kanamai		Malindi	
	EHWS - MHWN	MHWN - MTL	EHWN - MHWN	MHWN - MTL	EHWS - MHWN	MHWN - MTL
Ocypode cordimanus	-	-	P	-	-	-
O. ceratophthalmus	P	-	-	-	P	-
Dotilla fenestrata	-	-	-	P	-	P
Uca lactea	-	P	-	-	-	-

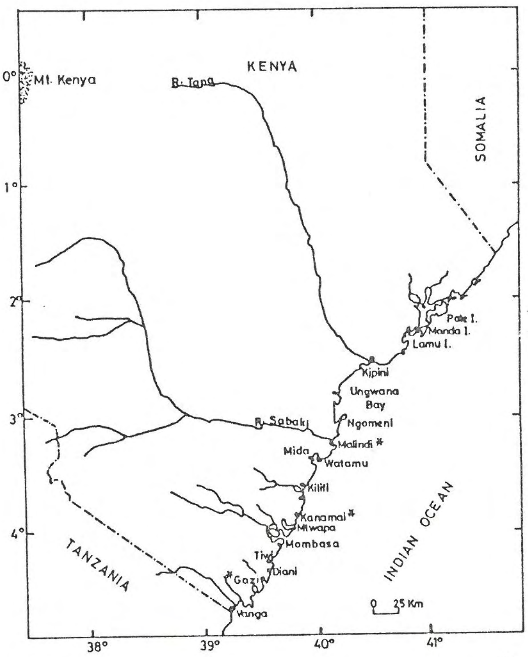

Fig. 1. Map indicating the study sites: Gazi, Kanamai and Malindi along the Kenya Coast

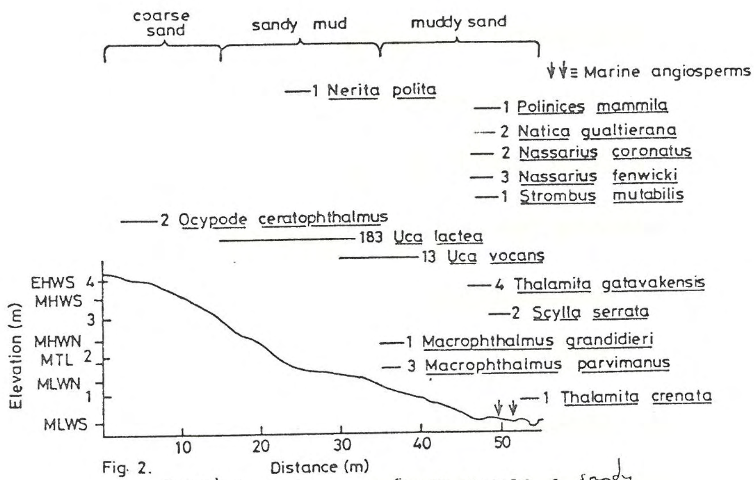

Fig. 2. Distribution of macrofauna across a sandy beach at Gazi

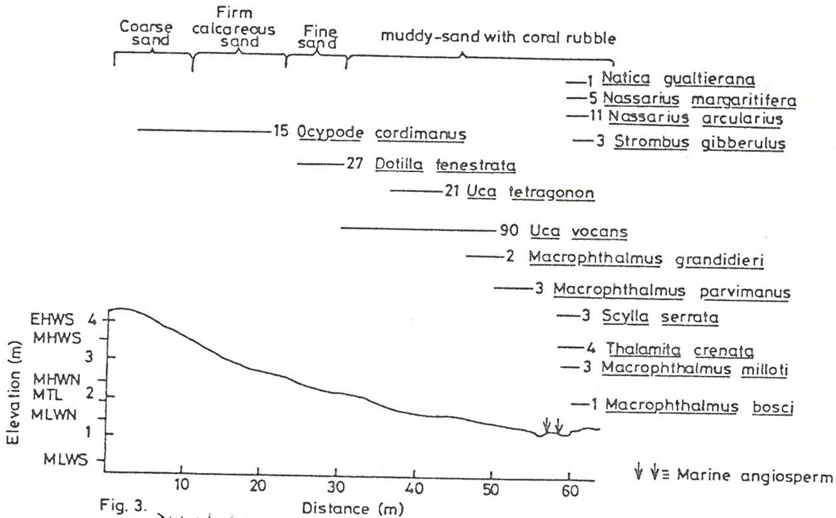

Fig. 3. Distribution of macrofauna across a sandy beach at Kanamai

Table 3. Distribution of various species in the lower levels of the sand beaches at Gazi, Kanamai and Malindi. The letter (P) indicates where the organism was seen and recorded.

Species	Gazi		Kanamai		Malindi
	MLWN - MTL	MLWN - MTL	MLWN - MTL	MLWN - MTL	MLWN - MTL
Uca tetragonon	-	-	P	-	-
U. vocans	P	-	P	P	-
Macrophthalmus bosci	-	-	P	P	-
M milloti	-	-	P	-	-
M.grandidieri	-	P	P	-	-
M. parvimanus	-	P	P	-	-
Scylla serrata	-	P	P	-	-
Thalamita crendta	-	P	P	-	-
T. gatava kensis	-	P	-	-	-
Natica gualtierana	-	P	P	P	-
Nassarius margaritifera	-	-	P	-	-
N. arcularius	-	-	P	-	-
N. fenwicki	-	P	-	P	-
N. coronatus	-	P	-	-	-
Polinices mammila	-	P	-	-	-
Strombus mutabilis	-	P	-	-	-
S. gibberulus	-	-	P	-	-
Nerita polita	P	-	-	-	-
Echinodiscus bisperforatus	-	-	-	-	P

Table 4. Geographical distribution in the Western Indian Ocean region of the sandy beach macrofauna recorded in this survey in Kenya. The letter (P) indicates where the organism was seen and recorded. The sources of records are as follows: Natal Province, South Africa (Barnard 1960; Broekhuysen and Taylor 1959; Day 1974; Day and Morgans 1956; Millard and Harrison 1953; Richards 1984), Mozambique (Barnard 1960; Macnae and Kalk 1962; Richards 1984), Tanzania Barnard 1960; Crosnier 1962, 1965; Hartnoll 1973, 1975), Somalia (Chelazzi and Vannini 1980; Vannini 1976, 1975), Madagascar (Crosnier 1962, 1965; Pichon 1966); Seychelles (Taylor 1968) and Aldabra (Taylor 1971 a). These countries and localities have been abbreviated as follows: South Africa (S.Af.), Mozambique (Moz.), Tanzania (Tan.), Kenya (Ken.), Somalia (Som.), Madagascar (Mad.) Seychelles (Sey.) and Aldabra (Ald.)

Species	S.Af.	Moz.	Tan.	Ken.	Som.	Mad.	Sey.	Ald.
Ocypode zone	P	P	P	P	P	P	P	P
O. ceratophthalmus	P	P	P	P	P	P	P	P
O. cordimanus	P	P	P	P	P	P	P	P
O. ryderi	P	P	P	P	P	P	-	-
Dotilla zone								
D. fenestrata	P	P	P	P	-	P	-	-
Hippa adactyla	P	-	P	P	-	-	-	-
Emerita austroafricana	P	P	P	P	-	-	-	-
Uca-Macrophthalmus zone								
Uca lactea	P	P	P	P	P	P	P	P
U. vocans	P	-	P	P	-	P	-	-
U. tetragonon	-	-	P	P	-	P	-	P
Macrophthalmus bosci	P	P	P	P	-	P	-	-
M. grandidieri	p	p	p	p	-	p	-	-
M. parvimanus	-	-	P	P	-	P	P	P
M. milloti	-	-	P	P	-	P	-	-
Thalamita crenta	P	P	P	P	P	P	P	P
T. gatavakensis	-	-	-	P	-	P	-	-
Scylla serrata	P	P	P	P	P	P	-	-

Natica gualtierana	-	-	P	P	P	-	-	-
Polinices mammila	P	-	P	P	P	-	P	-
Nassarius arcularius	P	P	P	P	P	-	P	-
N. coronatus	P	P	P	P	P	-	P	-
N. fenwicki	P	-	-	P	-	-	-	-
N. margaritifera	-	-	P	P	-	-	-	-
Strombus mutabilis	P	-	P	P	-	-	-	-
S. gibberulus	P	-	P	P	P	-	P	-
Nerita polita	P	P	P	P	-	-	P	-
Echinodiscus bisperforatus	P	-	-	P	-	-	P	-

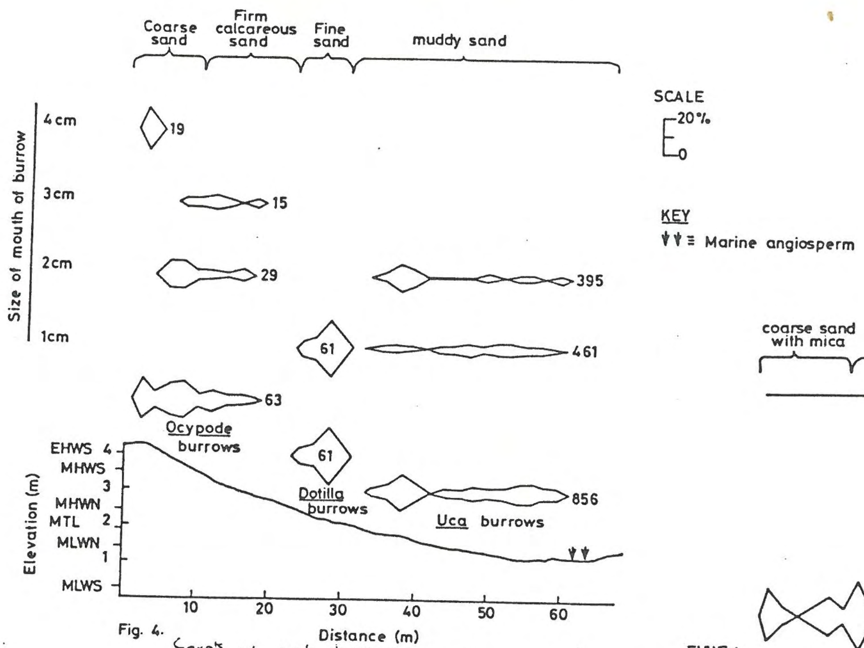

Fig. 4. Count of crab burrows across a sandy beach at Kanamai.

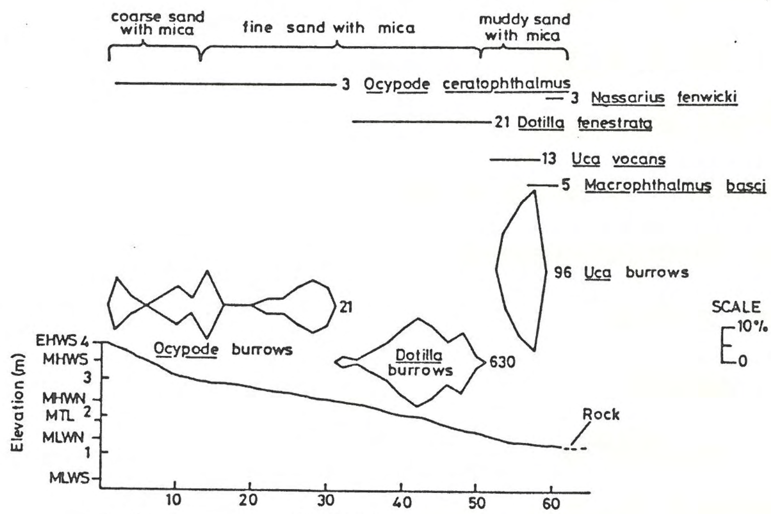

Fig. 5. Distribution of macrofauna and crab burrows across a sandy beach at Malindi Bay near Vasco da Gama pillar.

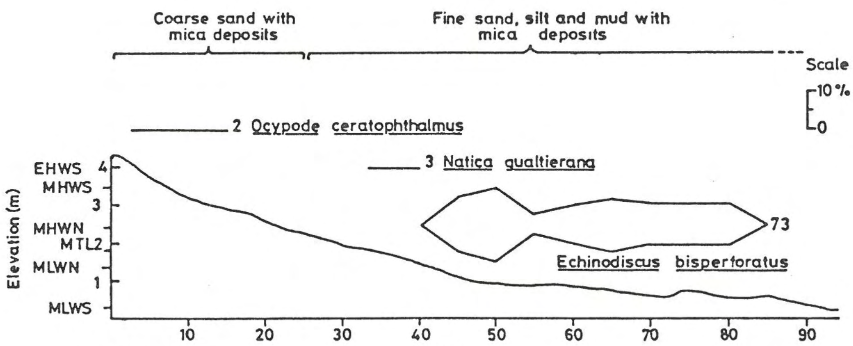

Fig. 6. Distribution of macrofauna across a sandy beach at Malindi.

6. PRAWN RESEARCH

PENAEID PRAWN POPULATIONS IN TUDOR CREEK

E.O. Wakwabi

Objectives of the study

1. To determine the magnitude of penaeid postlarval recruitment into the backwaters.

2. To trace by size progression, the growth in penaeus monodon in Tudor creek.

3. To determine the reproductive cycles and potential in P. monodon population in Tudor creek.

4. To examine gear development on the prawn fishery on the prawn fishery on the Tudor creek.

Results and discussion

Various sampling techniques were used to study aspects of larval-postlarval incursions into Tudor creek; recruitment into the backwaters and the fishery and the general growth processes as related to the environmental variations in the creek inshore waters.

Four penacid prawns species; Penaeus indicus, P. monodon, P. semiculcatus and Metapenaeus monoceros were shown to dominate in castnet fishery on the creek in the proportions 46.3%, 42.9%, 4.0% and 6.8% respectively.

Evidence is adduced on direct importation of the planktonic larvae from the offshore marine waters (spawning grounds) into near-shore and creek waters by way of currents and winds in conjuction with the inherent vertical migration in penaeid larvae. Peak incursions were observed between March and June months, but was shown to occur throughout the year. On a days scale, peak incursions were shown to coincide with night time on rising tides.

Juvenile-adolescent density were shown to very sharp seasonality for Penaeus spp. The highest densities were observed during the NE monsoon while the SE monsoon had generally low densities. A lunar effect was observed: better catches were observed on newmoon days than fullmoon days. Recruitment into the fishery was continous as emigration out of the creek.

The castnet fishery and Uzio fishery catch was examined to be exclussively on young (adolescent - subadult) prawn populations. No mature (or maturing) female specimens were encountered so far.

Environmentally, Tudor creek is dynamic. Tidal fluctuations are quite high (2.3 m range springs) hence water volumes accumulate in the creek and are exchanged during tidal changes. Water temperature remains average with only slight seasonal and diel pattern observable. Salinity varied with rainfall pattern.

Temperature, salinity and Ph examined together revealed some lateral stratification of the creek waters (esp considering the 5 station pattern). Conditions at the upper end of the creek provide for the nursery environment utilizable by penaeid populations. The Mangrove swamps, algal beds and silty shore waters enhance this.

Initial parameter estimates on growth and mortality were shown to be quite high: k = 1.25/yr, Lw = 85.5 mm CL and Z = 15.89 (r = 0.9801, n = 15). The high Z value is however expected to be due to avery high emigratory factor adding to the natural mortality (M) and fishing mortality (F). These parameters have however to be further tested for consistency.

Future Implications

1. Results of this study will form 100% of an M.Sc. thesis at the University of Nairobi.

2. Evidence so far obtained indicate that there is need to do extensive tagging (marking) / release experiments on the creek penaeids to trace with accuracy the recruitment and emigratory patterns in these populations. These experiments will also assist us to trace how far offshore the nurseryingpopulations in the creek spawn.

3. This creek has been identified as one of the areas along the Kenya coast with ample conditions for prawn farming. It would be important to initiate a culture programme on the creek where prawns can be farmed with least environmental degration i.e without clearing the existing mangrove systems.

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7. ALGAE RESEARCH

7.1. SEASONAL CHANGES IN MARINE FLORA ALONG KENYA COAST

G. Wamukoya

INTRODUCTION

Marine flora are a prominent feature of the intertidal zone of Kenya coast. Extensive studies have been carried out by various scientists in the systematics and identification of algae. Gerlaff (1960), Taylor (1966), Isaac (1967, 1968) Isaac and Isaac (1968), and Moorjani (1969, 1977, 1978, 1980) but these by no means exhaust the roll call of species. Marine flora extend from the low water level of neap tides (ie they are rarely exposed except at spring tides) to situations well beyond in deep water. Some are exposed for considerable periods during spring tides while others, although situated high on the shore grow in pools and depressions where certain amount of water is left by the receding tide.

The East African coast experiences monsoonal effect ie S.E. monsoon winds (March - September) and N.E monsoon winds (October - March), intertidal algae do suffer stress of dessication due to exposure to direct insolation and high temperatures at different times of the year. Algae show some kind of zonation within the intertidal zone and thus at the high tide level its even more distinct, within the same intertidal zone there will be marked differences between algae within the intertidal pools and the adjacent areas, several factors could be attributed to, for the difference these may include, salinity, substrate (rocky, sandy and muddy) and temperature.

Thus, the studies which have been carried out on Kenya coast have made no attempt to relate the occurence and distribution of the algae with the seasonal changes. Consequently, following successful studies on the systematics and identification of marine algae on the Kenya coast with the help of Dr. Coppejans (January 1986), it became necessary for detailed studies to be done to indicate the changes in the intertidal vegetation throughout the year in a diversity of localities along the Kenya coast (North and South coast). The study is also to determine the variation in the occurence and distribution of the intertidal vegetation in relation to the two monsoon periods ie N.E (October-March) and S.E (April-September) besides the effect of parameters like tidal effect, salinity, substrate and air temperature in relation to the occurence and distribution of the algae.

METHODS AND MATERIALS

Regular monthly samples are taken at ten stations which were selected as likely to be different yet characteristic areas. Of the ten stations; five are on the north coast and the remainder (5) on the south coast, to represent the whole coast. At the selected stations permanent transects have been made and thus the species found within the transect are identified and the paremeters ie air temperature salinity and substrata are recorded at every sampling time/site. Beside, those algal species which (could not be identified are carried to the laboratory for further microscopic work. The tide table is for the reference in relation to the time at which the low tides occur during the day. Thus all the information is computated in a tabular form for the whole one year duration. Therefore the vertical distribution of marine algae is studied by using the belt transect method.

RESULTS AND DISCUSSION

The results tend to indicate the following:

(a) Of all the algal species, there are certain species that occur along the coast (North and South) virtually throughout the year on different substrates.

(i) Sandy : This substratum is mainly occupied by Lyngbya majuscula, Enteromorpha kylini; Polysiphonia variegata and Centroseras clarilatum.

(ii) Rocky: Is a substratum of a wide range of species, but the most common that seem to occur throughout the year include: Gracilaria saliconrnia, Ulva tropica, Dictyosphaeria cavernosa, Rhizoclonium grande; Cladophoropsis sundanensis, Laurencia sp, Hypnea cornuta, Turbinaria sp Amphiroa fragillisima, Gelidiella acerosa; Pterocladia parva and chondria sp.

(iii) Muddy : Mainly occupied by sea grasses; Halophila ovalis and Thalasia hemprichii; with the following algae of common occurence: Halimeda reschii, Helimeda discoidea, Halimeda opuntia Halimedamacroloba, Codium geppii, Codium dwarkense, Galaxaura oblongata, Udotea palmetta and Avrainvillea erecta.

(iv) Sand covered shallow Rocky pools: Mainly occupied by Cystoseira myrica, Padina boryana Enteromorpha kylinii,Chaetomorpha indica, and Boerqesenia forbesii

(v) Deep Rocky Pools: Some of these pools support the growth of the seagrass Thalassiadendron ciliatum (formerly Cymodocea ciliata) on which Gracilaria corticata is an epiphyte. Other algal species include: Amphiroa fragilisima, Saragassum sp. Padina gymnospora, Chondrococcus hornemanii, Hypnea cornuta, Boergesenia forbesii, Hypnea pannosa, Sarconema filiformes and Dictyota bartayresii

(vi) Cliff: Cliff overhangs offer a good habitat for certain species of algae and these include: Bostrychia binderi, Bostrychia tenella, Cladophora sp and Murayella periclados.

(vii) Epiphytes: The most common epiphytes include: Chaetomorpha crassa, Enteromorpha Vamulosa, Cladophora mauritiana, Jamia pumila.

(b) There is more species diversity and high density of vegetation particularly the chlorophytes during the months of May - August, with the highest being in July - August which is within the S.E monsoon winds period. And there is less species diversity and low density of vegetation during the months November - February with the lowest being during the months December - February which falls during the N.E monsoon winds period. (refer to the tables 1 - 12).
This could be attributed to the fact that during the months of March - September is characterized by an influx of fresh water (low satinity) into the ocean from the inland and through underground seepage due to the rains and besides the temperatures during this period are relatively low ie 24.9 °C - 28.5 °C, hence this tends to favour the growth of certain species of algae particularly the chlorophytes and Centroseras Clavilatum (Red algae). Among the chlorophytes the following seem to be favoured E. kylinii, Ulva sp , Cladophora sp., Cladophoropsis sundanensis, Chaetomorpha indica, Boodlea composita.
The salinities range between 30.0 - 34.5‰ and compared to the normal marine salinity of 35.0‰

It is interesting and important too to note that during this time when we have the highest density of vegetation and species diversity the lowest spring tides occur during the night and hence the intertidal vegetation is not as such exposed to direct insolation during day light hours and thus avoiding the stress of high temperatures and dessication or drying. Whilst during the months of December - February when there is sparse algal growth the lowest spring tide occur during daylight hours, the salinities are high ie 35.0 - 36.5 (During this time there is no rain and reduced seepage of water) and the temperatures are high upto 33 C. Thus the exposure of algae to the combined stress of high temperature and high salinity could be a major factor behind the sparse vegetation since high temperature lead to drying and dessication of the algae and hence less population.

(c) There are some species which are found on the south coast and not on the north coast and the vice versa does not hold. For example Avrainvillea erecta has only been collected at Gazi (south coast) and not on the North coast. Therefore a general observation is that there is more species diversity of marine algae on the south coast as compared to the north coast. The verification as to why it is so is being investigated.

(d) The density of most Rhodophytes does not change throughout the year since they predominantly grow in the mid tide and low tide zones. These are in most cases are not subjected to much of the temperature and salinity effects except the tidal effect which is experienced as a result of high tides and the waves thus dislocating some of the species. Among the species that their density does not seem to vary include: Gelidiopsis variabilis, Gelidiella acerosa, Chondrococcus hornemanii, and Laurencia sp.

JULY 1986

ALGAL SPECIES	1	2	3	4	5	6	7	8	9	10	11
CHLOROPHYTES.											
E. Kylinii	C	C	C	C	R	C	R	R	R	R	R
E. clathrata	-	-	-	-	-	R	-	-	R	-	-
E. ramulosa	R	R	-	R	R	R	R	-	R	R	R
U. reticulata	R	R	R	R	-	C	R	R	-	-	A
U. pertusa	C	R	C	-	-	C	-	R	-	-	R
U. pulchra	C	R	R	R	R	C	C	C	-	-	-
U. fasciata	C	R	C	C	C	C	C	C	-	-	R
U. tropica	C	C	C	R	-	-	-	R	-	-	-
C. crassa	R	R	R	R	C	-	R	R	R	-	R
C. indica	C	R	R	R	-	-	C	-	-	-	-
R. grande	-	R	C	C	-	-	C	C	C	-	C
C. mauritiana	R	R	R	R	R	-	R	R	R	-	R
B. composita	C	R	R	R	R	-	-	R	R	-	R
C. sundanensis	C	C	R	C	R	R	R	C	R	-	C
V. pachynema	R	R	-	R	-	-	-	R	-	-	A
V. aegagrophila	C	R	R	R	C	C	R	C	C	-	A
B. forbesii	C	C	R	C	C	C	C	C	C	-	C
D. cavernosa	R	R	-	-	-	-	-	-	-	-	R
A. erecta	-	-	-	-	-	-	-	-	R	C	-
B. hypnoides	-	R	-	-	-	-	-	-	R	-	-
H. venschii	-	-	-	R	C	-	-	-	C	-	-
H. discoidea	-	R	-	-	-	-	-	-	-	C	-
H. macroloba	-	R	-	-	-	-	-	-	-	C	-
C. dwarkense	R	-	-	-	-	-	-	-	R	-	-
Cladophora sp 1	R	-	-	-	R	-	R	R	-	-	-
U. palmetta	-	-	-	-	-	-	-	-	-	A	-
H. opuntia	-	-	-	C	C	-	-	-	C	-	-
C. occidentalis	-	-	-	-	-	-	-	-	-	-	-
C. hilderbrandtii	-	-	-	-	-	-	-	-	R	R	-
C. comosa	-	-	-	-	-	-	-	-	-	R	-
H. tuna	-	R	-	-	-	-	-	-	-	-	-
PHAEOPHYTES											
D. bartayresii	R	-	-	-	-	-	-	R	-	-	-
D. dwaricata	R	-	R	-	-	-	-	R	-	-	-
P. boryana	C	C	-	R	R	R	R	R	R	-	R
P. gymnospora	C	-	-	-	C	C	R	C	-	-	-
P. tetrastromatca	R	-	-	-	C	-	-	R	-	-	-
T. conoides	R	-	-	-	R	-	-	R	-	-	-
T. tanzamensis	R	R	-	-	R	-	-	R	-	-	R
T. kenyaensis	-	-	-	-	-	-	-	-	-	-	-
T. onnataonata	R	-	-	-	R	-	-	R	-	-	-
T. decurrens	R	R	-	-	R	-	R	R	R	-	-
C. myrica	C	R	-	-	-	-	C	-	R	-	R
C. trinodes	-	-	-	-	C	-	-	R	-	-	-
Sargassum Sp.	C	C	-	-	C	C	C	C	C	-	R
RHODOPHYTES											
G. oblangata	R	-	-	-	-	-	-	-	-	-	-
G. obtusata	R	-	-	-	-	-	-	-	-	-	-
Gelidium Sp.1	R	-	-	-	-	-	-	R	-	-	R
W. miniata	C	-	-	R	R	-	R	R	-	-	-
G. aterosa	R	R	-	R	R	R	R	R	R	-	-
G. mynocladia	R	R	R	-	R	-	-	-	-	-	R

P. parva	R	R	-	R	R	R	R	R	-	-	-
P. nana	R	R	-	-	R	-	-	-	-	-	-
J. pumila	C	C	-	C	C	-	R	C	-	-	R
J. adherenis	R	-	-	-	-	-	-	-	-	-	-
A. fragilissima	C	R	-	C	C	C	R	C	C	-	C
A. rigida	-	-	-	R	C	-	-	R	-	-	-
Amphoroa Sp.1	-	-	-	-	R	-	-	C	-	-	R
G. salicornia	C	C	R	C	R	C	R	C	C	C	C
G. corticata	C	-	-	-	-	C	-	-	-	-	-
G. edulis	R	-	-	-	-	R	R	-	R	-	R
G. fergusoni	-	-	-	-	-	R	-	-	-	R	-
G. crassa	R	R	C	-	R	C	R	C	C	-	A
A. tribulus	-	-	-	-	-	-	-	-	-	-	R
G. variabilis	R	-	R	-	R	C	R	R	R	-	R
S. filiforme	C	R	-	C	C	C	C	C	R	-	R
H. pannosa	R	-	-	-	-	-	-	R	-	-	R
H. nidulans	C	-	-	-	-	-	-	-	-	-	-
H. cornuta	C	R	R	C	C	C	C	C	R	C	R
H. nidifica	-	R	-	-	R	-	-	-	-	-	-
H. musciformis	C	-	-	-	R	C	-	-	-	-	-
C. indica	C	R	-	-	R	-	C	-	-	-	R
C. globulifera	R	-	-	-	-	-	-	-	-	-	-
C. camonii	R	-	-	-	-	-	-	-	-	-	-
C. clavilatum	C	C	C	C	C	R	R	R	R	R	R
S. aculeata	R	R	-	R	R	R	C	R	R	-	R
Polysiphonia Sp.	-	R	-	-	-	-	-	-	-	-	-
M. periclados	R	-	-	-	R	-	C	R	-	-	-
B. tenella	R	-	-	-	R	-	R	R	-	-	-
B. ginderi	C	-	-	-	C	-	C	C	-	-	-
A. glomerata	R	-	-	-	-	-	-	-	-	-	-
V. fimbriata	R	-	-	-	-	-	-	-	-	-	-
C. dasyphylla	C	C	R	R	-	R	-	R	-	-	R
C. hornemanii	C	R	-	R	R	-	-	C	-	-	R
A. spicifera	R	R	R	R	R	C	R	R	R	R	R
L. perforata	R	-	-	-	-	-	-	-	-	-	-
L. papillosa	C	R	R	R	R	R	-	R	-	-	R
L. collumelaris	-	-	-	-	-	-	-	R	R	-	-
A. nana	R	R	-	-	R	-	R	R	-	-	-
Gracilaria sp	-	-	-	-	-	-	A	R	C	-	-
Geldiaceae sp.1	-	-	-	-	-	-	-	C	-	-	-
H. venusta	-	-	-	-	-	-	-	-	-	-	R

KEY : R = Rare   C = Common   A = Abundant

FEBRUARY 1987

ALGAL SPECIES	1	2	3	4	5	6	7	8	9	10	11
CHLOROPHYTES											
E. kylinii	R	C	R	R	C	C	C	C	R	R	C
E. clathrata	-	-	R	C	-	-	-	-	-	-	-
E. ramulosa	-	R	-	-	-	-	-	-	C	R	-
U. reticulata	A	C	-	R	R	A	C	R	-	-	R
U. pertusa	C	-	-	-	C	R	R	R	C	-	-
U. pulchra	R	R	-	-	R	C	R	R	-	-	-
U. fascrata	C	-	C	R	C	C	C	C	R	-	-
U. tropica	-	R	-	-	R	-	-	-	-	-	R
C. crassa	R	R	-	R	C	-	C	C	R	-	R

C. indica	-	-	-	-	-	-	C	R	-	-	-
R. grande	-	-	C	R	-	-	C	C	-	-	C
C. mauritiana	R	R	-	-	R	R	C	C	-	-	-
C. patentirames f. Longiarticulata	-	-	-	-	-	-	-	-	-	-	-
B. composita	-	R	-	-	R	R	R	C	-	-	R
M. montagnei	-	-	-	-	-	-	-	-	-	-	-
C. sundanensis	R	-	-	-	-	R	-	A	-	-	R
V. pachynema	R	R	-	-	-	R	-	R	-	-	R
V. aegagrophila	-	-	-	-	R	C	-	R	R	-	R
B. forbesii	C	C	R	R	C	R	C	C	R	-	R
D. cavernosa	C	R	-	R	R	-	R	C	-	-	R
A. erecta	-	-	-	-	-	-	-	-	C	R	-
B. hypnoides	-	R	-	-	-	-	-	-	C	-	-
C. racemisa(macrophysc)	C	-	-	-	-	-	-	-	-	-	-
H. renschii	C	-	-	C	C	-	-	-	-	-	-
H. discoidea	R	R	-	C	-	-	-	-	C	C	-
H. maeroloba	-	R	-	R	-	-	-	-	-	-	-
C. dwaruense	R	-	-	-	-	-	-	-	-	C	-
Cladophora	R	-	-	-	R	-	R	R	-	-	-
U. palmetta	-	-	-	-	-	-	-	-	-	A	-
H. opuntia	-	-	-	R	R	-	-	-	-	-	-
C. ociidentalis	R	-	-	-	-	-	-	-	C	-	-
<u>PHAEOPHYTES</u>											
D. gartayresii	R	-	-	-	-	-	-	-	-	-	-
D. dwaricata	R	-	-	-	-	-	-	-	-	-	-
P. bonyana	C	C	-	-	R	R	R	R	-	-	R
P. gymnospora	C	-	-	-	C	C	-	C	-	-	-
P. tetrastomatica	R	-	-	-	R	-	-	R	-	-	-
T. conoides	R	-	-	-	C	-	-	C	-	-	-
T. tanzaniensis	R	R	-	-	R	-	-	R	-	-	-
T. decurrens	R	-	-	-	C	-	-	R	-	-	R
T. kenyaensis	R	R	-	-	R	-	-	R	-	-	-
T. ornata orńata	-	-	-	-	R	-	-	R	-	-	-
C. myrica	R	-	-	-	-	-	-	-	-	-	R
C. trinodes	-	-	-	-	C	-	-	C	-	-	-
Sargassum sp	R	-	-	R	R	R	R	R	-	-	-
<u>RHODOPHYTES</u>											
G. oblongata	R	-	-	-	-	-	-	-	-	-	-
G. obtusata	R	-	-	-	-	-	-	-	-	-	-
Gelidium sp1	-	-	-	-	-	-	-	C	-	-	-
W. miniata	R	-	-	-	R	-	-	R	-	-	R
G. acerosa	R	R	-	R	R	R	-	C	-	-	C
G. myriocladia	-	-	-	-	R	-	-	R	-	-	R
G. parva	R	-	-	-	R	R	-	R	-	-	R
P. nana	-	-	-	R	-	-	-	R	-	-	-
J. pumita	C	-	-	C	C	R	-	C	R	-	-
J. adherens	-	-	-	-	-	-	-	R	-	-	-
A. fragilissima	C	R	R	R	C	R	-	C	C	-	R
A. rigida	R	R	-	-	R	R	-	R	-	-	R
Amphrioa sp1	-	-	-	-	-	-	-	R	-	-	-
G. salicornia	C	C	R	R	-	C	C	R	R	C	R
G. corticata	R	-	-	R	R	C	-	R	-	-	-
G. edulis	-	-	-	-	-	R	R	-	R	-	-
G. fergusoni	R	-	-	-	-	-	-	-	-	-	-
A. tribulus	-	-	-	-	-	-	-	-	-	-	C
G. variabilis	R	-	-	-	R	C	-	R	-	-	-

S. filiforme	C	R	-	R	R	C	R	R	-	-	R
H. pannosa	R	R	-	-	R	-	-	-	-	-	-
H. nidulans	R	-	-	-	-	-	-	-	-	-	-
H. cornuta	C	C	R	R	C	C	C	C	R	-	R
H. nidifica	R	R	-	-	-	-	-	-	-	-	-
C. indica	C	-	-	-	R	R	R	-	-	-	-
C. globulifera	R	-	-	-	-	-	-	-	-	-	-
C. camouii	R	-	-	-	-	-	-	-	-	-	-
C. clavilatum	C	C	R	R	R	R	R	R	-	-	-
S. aculeata	R	R	-	R	R	R	-	-	-	-	-
Polysiphoma sp	R	R	-	-	-	-	-	R	-	-	-
M. periclados	R	-	-	-	R	-	R	R	-	-	-
B. tenella	R	-	-	-	R	-	R	R	-	-	-
B. binderi	C	-	-	-	C	-	C	C	-	-	-
A. glomerata	R	-	-	-	-	-	-	-	-	-	-
V. fimbriata	R	-	-	-	-	-	-	-	-	-	-
C. dasyphylla	C	C	-	-	-	-	-	R	-	-	-
Chondrocollus hornemanii	R	R	-	-	R	R	-	R	-	-	-
A. spicifera	R	R	-	-	R	R	-	R	-	-	-
L. perforata	R	-	-	-	-	-	-	-	-	-	-
L. papillosa	R	R	-	-	-	R	R	R	-	-	-
L. columellaris	R	R	-	-	-	-	-	-	-	-	-
A. nana	R	R	C	-	R	-	-	R	-	-	-
Gracilania sp	-	-	-	-	-	-	C	R	R	-	-
Gehdiaceae sp 1	-	-	-	-	-	-	-	C	-	-	-
H. venusta	-	-	-	-	-	-	-	-	-	-	R

KEY

1= Mackenzie Point
2= Mkomani
3= Old Nyali
4= Reef Hotel
5= Kanamai
6= Malindi
7= Diani
8= Tiwi
9= Gazi
10= Port Reitz
11= Fort Jesus

7.2. MARINE ALGAE FROM E. AFRICAN COAST

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70992

INTRODUCTION

Marine environment is distinguished from the fresh water environment primarily by its higher salt content. It is possible of course, to consider the marine world as a single Ecosystem, but such an Ecosystem would be far too vast and complicated. Dividing this into smaller Ecosystems means that these will not be mutually independent and the degree of independence will differ from one to the next. It is probably best and in accord with general practice to separate Oceanic and Estuarine Communities and then Planktonic and Benthic communities. We can thus consider these four communities and their habitats as four Ecosystems. In this age the algae are altogether dominant in the marine environment particularly the Macroscopic algae inhabit the Estuarine benthic and Oceanic benthic ecosystems whereas the microscopic algae (phytoplankton) inhabit the planktonic Ecosystems (floating).

The plant life in the sea is extremely rich and some exploitation of these resources has taken place over hundred of years. At the present time, when man is increasingly turning his attention to the Ocean as a major source of food and industrial chemicals, the plant life both attached and floating, is becoming of great importance. The great amount of attached sea weed existing in the world is probably not fully realized, if it were it is possible that greater efforts would have been made in the past to find means of collecting and using all this raw material the minute floating plants of the sea, the phytoplankton form the basic foodstuff for small animals and fish and do not themselves have a direct commercial use, although recent work indicates that artificial food chains in mariculture systems utilizing phytoplankton as the basic trophic level are feasible.

CLASSIFICATION

For the purpose of this paper I'll basically be concerned with the macroscopic algae and hence four major groups of macroscopic algae make up most of the benthic flora: the Cyanophyta (Blue-green algae), the Chlorophyta (green algae), the phaeophyta (Brown algae) and the Rhodophyta (Red algae). Sometimes they are called as seaweeds. The term seaweed itself does not have any taxonomic value, but is rather a popular term used to describe the common large attached (benthic) marine algae. These are all of world wide distribution, but their numbers and proportions vary in different climates.
The algae differ from the higher plants in that they do not possess true roots, stems or leaves. However, some of the larger species, upon which the industries are primarily based possess attachement organs or holdfasts, that have the appearance of roots and there may also be a stem-like portion called stipe, which flattens out into a broad-leaf like portion or lamina (eg.

Laminaria) some species consist simply of a flat plate of tissue eg. ulva whilst in others, the plant body of thallus is composed of a narrow compresseed or tubular axis with similar branches arising from it eg Gelidium. The smaller species differ from those described above in that they are mainly filamentous eg.cladophora.

1. CYANOPHYCEAE {BLUE GREEN ALGAE}

Although the most prevalent occurences of the Blue green algae are in fresh water, terrestrial, and aerial habitats, these plants are ubuquitous and widely adapted to diverse brackish and strictly marine environments. They are usually inconspicous in the marine benthos compared with the larger and more abundant green, brown and red algae. Unlike the other benthic algae groups which contain a great range of forms, from very simple unicells or filaments to highly complex thalli, marine blue green most of the species occur as simple, Uniseriate filaments commonly within a stratified and coloured mucilaginous or gelatinous sheath. The cells are usually provided with bluish green pigments, although purplish and reddish forms are not rare. Nuclear differentiation is of a very low order and no certain evidence of sexual reproduction has been obtained. There are no flagellated reproductive elements in the group.

The methods of reproduction in blue green algae are generally simple and very largely vegetative, although endospores and akinetes occur in as number of genera. In addition to simple cell division, a more specialized kind of vegetative multiplication occurs in some of the filamentous groups in which hormogonia are formed. Heterocysts of other kinds and positions than those that function in hormogonium formation occur in filamentous forms.

A more specialized reproductive method in various filamentous forms is through resting spores (Akinetes). Although Akinetes may be capable of germinating soon after being formed, they are commonly very resistant to desiccation and temperature extremes, and may germinate only after a resting period. Another method of spore reproduction in cyanophyte groups is by non-resistant endospores (do not undergo a resting period).

The taxonomy of blue green algae has been extra ordinarily complicated by the remarkably wide geographic ranges of these plants their extreme adaptablity, and their morphological variability. They are Chroococcaceae, Chamaesiphonaccae, oscillatoriaceae, Nostocaceae, Rivulariaceae, Scytonemataceae, Stigonemataceae.

CHROOCOCCACEAE

The family Chroococcaceae consists of plants either spherical (coccoid); ovoid or cylindrical cells which become separated from one another by gelatinous sheath material after each division. These include Anacystis sp.

OSCILLATORACEAE.

Is by far the largest family in the blue-green algae and includes all the relatively simple forms in which the trichomes are unbranched and develop neither heterocysts nor hairs. These include genera: Oscillatoria, Symploca, Lyngbya,Microcoleus, Schizothrix:

NOSTOCACEAE:

The Nostocaceae resemble the Oscillatoraceae in their diffuse growth and the unbranched structure of the trichomes but are distinguished by the prevalent production of heterocysts and frequent reproduction by akinetes. The common genus isHormoth amnion. RIVULARIACEAE genus calothrix. SCYTONEMATACEAE: genus scytonema.

STIGONEMATACEAE.

Some of the largest and most elaborately organized blue-green algae are included in Stigonemataceae. The plants are characterized not only by trichomes exhibiting true branching but there is in many a strong tendency to multiseriate construction and heterotrichy. Genera Mastigocoleus and Stigonema.

2.CHLOROPHYTA {GREEN ALGAE)

Marine benthic green algae, unlike freshwater ones are primarily macroscopic forms. A few minute species occur but most are large enough to be recognized in the field as green algae simply by their colour. Marine green algae have well defined often thick and stratified cell walls consisting of an inner layer of cellulose or callose, and an outer pectic layer. Except for the challiness of calcareous forms, a majority of green algae are recognised by their grass-green colour for their pigment complex of chlorophyll a, chlorophyll b, xanthophylls and carotenes is like that of flowering plants.
Although most terrestrial green algae have uninucleate cells, a large majority forms are multinucleate.

CLASSIFICATION

Chlorophytes may be divided into volvocales, Ulotrichales Chaetophoraceae, Monostromaceae, Ulvaceae, Cladophoraceae, Anadyomenaceae, Valoniaceae, Siphonoclaoceae, Boodleaceae, Derbesuaceae, Caulerpaceae, Bryopsidaceae, Codiaceae and Dasycladaceae.

VOLVOCALES

Consists largely of planktonic fresh water green algae in which the vegetative cells are flagellated and motile eg. common marine form is Platymonas. Otherwise the rest are classical colonial Volvox.

ULOTRICHACEAE

Contains marine fresh water and aerial forms. The plants are filamentous or membranous and consist of Uninucleate cells with a parietal chloroplasts. These include. *Ulothrix*.

CHAETOPHORACEAE.

The family contains a number of genera and species of small marine plants which characteristically grow on or in the tissue of seaweeds or in the shells and surface structures of animals. eg.*Entocladia*.

MONOSTROMACEAE

Monostroma sp is the broad and traditional sense, is a widespread green alga of marine and brackish waters readily recognized by its membranous thallus consisting of a single layer of Pseudoparenchymatous cells.

ULVACEAE.

Members of the Ulvaceae, especially the genera *Ulva* and *Enteromorpha* are the most conspicuous of the green algae in the oceans. They occur in all seas and often are prevalent in brackish or polluted areas, or in salt marshes.

CLADOPHORACEAE.

This family contains many fresh water forms some of the genera include *Cladophora*, *Chaetomorpha* and *Rhizoclonium*.

ANADYOMENACEAE.

This is a small family of strictly Marine tropical algae. The two principal genera,*Microdictyon* and *Anadyomene*.

VALONIACEAE.

The principal genera here are *Valonia* and *Dictyosphaeria*.

SIPHONOCLADACEAE.

This family consists of several predominant tropical genera having a habit of loose clusters, tufts or mats of freely branched axes. The largest genus is *Cladophoropsis*.

BOODLEACEAE.

This small family contains two equally common pantropical genera. *Boodlea* and *Struvea*. In both of these the thallus is reticulate, composed of a branching network of uniseriate filaments.

DERBESIACEAE.

The principal genera are *Derbesia* and *Halicystis*.

CAULERPACEAE.

This family contains a single large, widely distributed genus _Caulerpa_.

BRYOPSIDACEAE.

This is another small family of only 2 genera of which _Bryopsis_ is widespread in most temperate and tropical regions.

CODIACEAE.

The genera included in this family include: _Chlorodesmis_, _Halimeda_, _Codium_, _Udotea_ and _Penicillus_.

DASYACLADACEAE.

The main genera include _Acetabularia_ and _Neomeris_.

3. PHAEOPHYTA {BROWN ALGAE}

The Phaeophyta are the most strictly marine of all the seaweeds. The marine brown algae are in large part macroscopic plants. There are no unicellular or colonial forms, nor any so simple of construction; as an unbranched filament. The smallest forms of Ectocarpales consists of branced uniseriate filaments endophytic in larger seaweeds, while the largest members of laminariales or fucales exhibit a size and an elaboration of form and structure exceeding that of any other algae.
The characteristic brownish colour of Phaeophyta is due to the special accessory carotenoid pigment, fucoxanthin, which masks the other pigments, including chlorophyll a and c. The chromatophore may be solitary in a cell, but usually there are many small parietal chromatophores. Unlike large numbers of marine green algae, the Phacophyta usually have cells with a single large nucleus.

The brown algae have been divided into three classes according to the type of life history. These are :-

(i) Class Cyclosporeae; which includes Fucales genera; _Fucus_, _Ascophyllum_, _Pelvetia_, _Pelvetiopsis_, _Sargassum_, _Durvillea_ and _Cystoseira_.

(ii) Class Isogeneratae includes orders:

(a) Ectocarpales:- Genera _Ectocarpus_ and _Ralfsia_

(b) Sphacelariales:- Genus _Sphacelaria_

(c) Dictyotales: This distinctive order is of widespread occurence in tropical and sub-tropical regions. The genera include _Dictyota_ and _Padina_.

(iii) Class Heterogeneratae; includes orders:

(a) Chordariales: Genera _Myrionema_, _Elachista_ and _Chordaria_

(b) Sporochnales: genus Sporochnus.

(c) Dictyosiphonales: includes genera Punctaria Scytosiphon, Colpomenia, Hydroclathratus, Rosenvingea and Dictyosiphon.

(d) Laminariales: This order contains the largest and most elaborately organized of all algae. This includes genera: Laminaria, Macrocystis, Neriocystis, Pelagophycus, Postelsia, Eisemia and Alaria.

4. RHODOPHYTA (RED ALGAE)

A majority of the different kinds of seaweeds of the world are red algae. There are more of these (about 4000 species) than of all the several other major groups combined, and they occupy the entire range of habitats from highest intertidal levels to the lowermost limits of light. They occur as minute filamentous epiphytes, as thin, epilithic films, and as large, fleshy, or membranous forms sometimes reaching a few metres in length. Most of them grow attached to rocks or other algae. Few are sand-dwelling forms like the calcareous greens, and there is no red alga capable of prolonged life in the floating state, as is Sargassum. The great majority of deep-water algae are Rhodophyta.

The red algae may be distinguished from Phaeophyta and Chlorophyta by a number of characteristics, but colour is not a uniformly remarkable one. Although only infrequently will red and green algae be confused on account of colour, there are kinds of Grateloupia, for example, that may be as green as Ulva. It is in the higher intertidal zone that the student most often mistakes Rhodophyta for the pigments of some of the former may be so dense and the bright red Phycoerythrin so masked by other pigments that the characteristic red colour is not recognizable. Well shaded or subtidal Rhodophyta, however, are almost invariably of pink or red colour because of dominant phycoerythrin. With only two exceptions (Porphyridium, Rhodosorus) the marine Rhodophyta are all multicellular plants. The thallus is usually of fundamentally filamentous construction, although this may be obscured by dense compaction and modification of adult cells to form Pseudoparenchymatous tissues. The cells are generally Uninucleate, although many species have multinucleate cells. The nuclei are usually small and inconspicuous.

More definitive characteristics of Rhodophyta are seen in their manner of sexual reproduction. Unlike the situation in brown and green algae no flagellated reproductive bodies occur. The nonflagellated male gametes (spermatia) reach a fixed female reproductive cell (the carpogonium) by passive movement in the water medium.

Due to the vastness of the group, for the sake of this paper only the most common families on the Kenya coast will be discussed. These include families:

(a) BANGIACEAE:
Two representatives of this family: Bangia and Porphyra are widely distributed.

(b) ACHROCHAETIACEAE
The family contains a large number of minute epiphytic and endophytic plants of uniaxial, branched-filament construction. Genera Acrochaetium and Rhodochorton

{c) HELMINTHOCLADIACEAE
Includes Genera Nemalion and Liagora

(d) CHAETANGIACEAE
The plants of this family are all moderate size and bushy habit multiaxial in structure and with a continuous surface layer of specialized compacted cells. Includes Genera Galaxaura and Actinotrichia.

(e) GELIDIACEAE
The species are common and widely distributed. Some are of considerable economic importance. Most members are plants of moderate size, of firm cartilaginous consistency, of uniaxial construction and of monopodial branching. Includes genera Gelidium, Pterocladia, Gelideopsis, Wurdemannia, and Gelidiella

(f) CORALLINACEAE.
This is the largest family of the order and is made up of a great diversity of forms almost all of which are heavily caluified. Includes genera Melobesia, Lithothamnium Lithophyllum, Jania, Amphiroa and Corallina

(g) CRYPTONEMIACEAE
This mainly comprises the genus Grateloupia

(h) HYPNEACEAE
The plants are bushy, tufled or clustered forms with cylindrical branches provided with many short, spine like lateral branchlets. Consists of genera Hypnea.

(i) GRACILARIACEAE
This family includes several genera that have small numbers of species and a large one, Gracilaria with numerous species widely distributed throughout temperate and tropical waters of the world. The plantsare all fleshy types tending to be flattened to foliose and of pseudoparenchymatous structure without filamentous cells in the mature vegetative thallus.

(j) GIGARTINACEAE
Comprises of the genus Gigartina

(k) RHODYMENIACEAE
This gen us contains numerous species of foliose plants usually with dichotomously or palmately branches blades Rhodymenia.

(l) CHAMPIACEAE
Mainly of the genus Champia.

(m) CERAMIACEAE

This large family is composed mainly of very delicate plants mostly of cylindrical construction. They may be uniseriate uncorticated filaments or they may be partially or wholly corticated, but the corticating cells are never as long as the cells they enclose (not polysiphonous). Includes genera Antithamnion and Ceramium.

(n) DASYACEAE

The plants consists of slender, cylindrical solid axes clothed with abundant fine hairs which tend to obscure the apical development. Includes the genus Dasya.

(o) RHODOMELACEAE

The family includes a great diversity of vegetative types but a remarkably well defined and uniform reproductive development. The most striking character of the Rhodomelaceae is the polysiphonous structure whereby axial cells cut off by longitudinal walls form a series of pericentral cells according to a regular sequence. Includes the genera Polysiphonia, Chondria and Laurencia (The last two genera are fleshy Rhodomelaceae with extensive cortical development).

USES OF ALGAE

1. Fodder

Its principal value is regarded as being in the iodine and mineral content (trace elements) because the various elements are naturally dispensed. The trace elements are present in organic form which makes them more readily assimilated. It is therefore, valuable on mineral defficient pastureland. eg. Laminaria, Fucus, Ascophyllum and Sargassum.

2. AS MANURE

It is mainly the large brown algae, wracks and oarweeds that are used for manure. Other species have been employed if they are washed up in sufficient quantity eg. Ulva Lactuca which is rich in nitrogen, drift weed that collects on the shore is never or but rarely composed solely of the brown weeds, and it usually contains an admixture of red and green algae. The steady use of the seaweed manure completely obviates any necessity for a rotation of crops, which would otherwise have to be practised. This fact, though is somewhat surprising in view of the deficiency of phosphates in the algae. Apart from the brown algae, certain of the red seaweeds which produce lime (calcium carbonate) are used in some areas for a special purpose. These particular seaweeds are principally Phymatolithon calcareum and Lithothamnion coralloides.

The seaweeds are of a special value because of high calcium carbonate content (up to 80%) and they are therefore employed instead of ordinary lime in order to sweeten humus rich acid or peaty soils. It has been found that seaweed manure dug into the soil to a foot below the surfaces increases the fruiting period of tomatoes and it has also been claimed that it renders them from blight. There is also a report that potatoes grown on land manured with seaweed are less susceptible to scale disease and also to virus disease known as leaf curl. The alga mainly in use is Fucus serratus. In the southern hemisphere, coast dwellers in New Zealand have made use of algae as manure Macrocystis pyrifera, Lessonia variegata and Ecklonia radiata, Carpophyllum sp, Cystophora sp and Sargassum sp are used. The principal objection about the use of these algae is that they are heavy bulky material and hence, unless dried, it must therefore be utilized near its source, it is therefore, only profitable to establish an Industry in places where large quantities are likely to be continually available.

Little (1948) studied the rate of decomposition of certain large New Zealand brown seaweeds when dug into the soil. Macrocystis, Ecklonia and Durvillea decompose completely within four months but Carpophyllum is still recognizable after one year. The bulk of the sodium, potasium and chlorine is released in the first fourteen days so that these elements are made available very rapidly. It is likely therefore that the minor elements will be made available equally rapidly. In Japan algae which are not used for other purposes are used for manure, either alone or with other materials (Davidson 1906). In Haina, India and Ceylon, Ssargassum sp together with Gracilaria sp are used for coconuts and coffee brushes. Sea weed as coconut manure is also recorded from Brazil where the red alga Hypnea is most used besides Ulva sp and Enteromorpha sp. In south Africa a mixture of Ecklonia maxima and Laminaria eallida is sold as a soil conditioner.
In recent years dried seaweed meal and liquid extracts have been increasingly employed by horticulturists. Market gardeners, farmers ad orchardists with gradual exhaustion of presently known mineral fertilizer supplies over the next centuries, it is likely that even more use will be made of this annually renewable source. Dried meal comparable to that used for animal fodder obviously takes longer to be effective than a liquid extract because it must undergo bacterial breakdown. The dried meal, with its slow release of alginic acid and other polyuronides, represents a better soil conditioner than does a liquid extract. used in crops such as potatoes, asparagus, flowers, fruits but not for cereals. The liquid extracts operate more rapidly because the compounds are already dissolved and in a state that the plants can use. There is absorption also through the leaves as well as through the roots.

In recent years various liquid extracts of brown algae have appeared on the market. United Kingdom brands are 'Maxicrop' and alginure whilst 'Seagro' is manufactured in New Zealand. Maxicrop is primarily used for gardens Orchards and field crops, It is wide spread and is exported to Australia, Canada, Falkland Islands, Finland, Ghana, Jamaica, Kenya, Malawi, Mauritius, Nigeria, U.S.A, Zambia and Zimbabwe. Made mainly from Ascophyllum. There are experiments which indicate that seaweed extract has the effect of releasing phosphorus that is normally bound within the soil. The manurial value is based on the fact that all algae are relatively high in nitrogen and potash but they are low in phosphorus content.

Many plants require minute quantities of certain elements if they are to grow properly, if sufficient of these element is not present the plants suffer, in the same way as animals, from what are known as deficiency diseases. The symptoms of these diseases are varied but they frequently involve changes or 'burning' of leaves. Seaweed manure may be valuable because it contains a number of these trace elements eg. Manganese, Boron, Barium, Molybdenum, Iron, Zinc, Copper and Cobalt.

Whilst much has been made of the trace elements present in dried seaweed or in the liquid extract as a basis for the results observed when either are used for plant growth, recent studies tend to suggest that it may really be the growth hormone content that is responsible for the results eg. promotion of seed germination, increased frost hardness, increased resistance to fungal and insect pests. It has been known for some time that auxins and gibberellins are present in the large brown seaweed this include, Laminaria ,Ascophyllum and Fucus sp. and both these compounds are known to be important in the growth of terrestrial plants as well as that of the algae. These growth hormones are apparently released fairly steadily from the algae because Fries (1973) has reported their presence in coastal waters.

3. ALGAE FOR ENERGY SOURCE.

The conversion of large brown algae to Methanol presents no great problem and this can be converted economically to gasoline (Wise and Silvestry 1976). It is likely that a similar process will enable the conversion of ethanol to gasoline to be equally economic. The concept of the kelp farm has been developed to ensure adequate supplies of algae that can be harvested economically. At present time attention is centred around the large pacific kelp Macrocystis pyrifera which grows in extensive beds that are regularly harvested off the Pacific U.S.A.. This algal genus also occurs off the coasts of south Africa, South America, Australia and New Zealand.
For this reason it will be wisest to restrict kelp farms to ocean areas where the alga grows naturally.

4. AS VEGETABLES.

Seaweeds as a staple item of diet has been used in Japan and China for a very long time. There are, however, many Islands where conventional agriculture cannot meet local demands, and it is here that people have a necessity relied on the sea as a major source of food.

4.1 Chlorophyceae
Among the green algae the sea lettuce (Ulva lactuca) used to be eaten as a salad and it has also been used in soups. It is however, a food with a taste that needs to be a acquired. The species of Ulva are eaten today throughout the west Indies and in Barbados they are employed to make a 'bush' tea. Other green algae which are edible include; U. fasciata; E. flexuosa; E. intestinalis, Codium sp and Caulerpa clavifera

4.2 Phaeophyceae
Among the brown algae those edible include:
Dictyopteris polypodioides and Sargassum echinocarpum

4.3 Rhodophyceae
Among the Rhodophytes there are a few which have been used for food. Rhodymenia palmata has been eaten in Iceland along with

dried ash, butter and potatoes, and in times of famine was even baked into bread. In Canada it is used as a 'nibble' with beer, USSR it is fermented into an alcoholic beverage. In west Indies jellies are prepared in Trindad and Jamaica from species of Gracilaria; Eucheuma isiforme are eaten. Other Rhodophytes may include Laurencia pinnatifida, Hypnea nidifica, Gelidium sp and Grateloupia filicina.

4.4 Cyanophyceae

Two blue green terrestrial algae, Nostoc commune and Nematonostoc flagelliforme are still used by the Chinese of the interior as food.

Since large quantities of seaweed are available around the coasts of many countries all that is required is the labour to gather them. The fact that few are eaten in western countries is probably mainly due to palatability. However, the supply of food for the increasing world population will become an increasingly serious problem and use of seaweeds may have to become more widespread.

Nutritional Value

The principal components of the edible algae are carbohydrates, small quantities of protein and fat. Ash which is largely composed of sodium and potasium and 80 -90 per cent of water. Apart from these major constituents sea vegetables are rich in essential trace elements.

(i) Iodine and goitre

The use of algae and algal products in the orient is regarded as the principal reason for the lack of goitre. This may have been achieved, unconsciously, but on the other hand it does represent a real contribution to national health. Laminaria sp and Codium intricatum are rich in iodine whilst Gelidium sp and Grateloupia sp contain a medium amount .

(ii) Vitamins.

At the present time the supply of food is becoming a serious problem and in particular there is the daily need of man for certain important minor items like vitamins. Algae are rich in vitamins A, B and B vitamin C and E. With the exception of calcium and phosphorus 100g of algae provide all that a human being needs in respect of sodium potasium and magnesium.

Vitamin A found in Ulva lactuca and Codium sp. Vitamin B, found in U. lactuca, Enteromorpha, Monostroma, Laminaria, Poryphyra, Rhodymenia pertusa and Chondrus crispus

Vitamin B mainly Laminaria sp.

Vitamin C, U. lactuca, Enteromorpha, Porphyra perforata (richer) and Gigartina papillata.

Vitamin B (Riboflavin) mainly in Chondrus and Porphyra.

There is no doubt that whatever may be the direct food value of algae, they are useful because of their iodine content which serves as a protection against goitre whilst the bulk and prevent constipation.

5. AGAR AGAR

This is a product prepared from certain species of Rhodophytes.

The term 'Agarophytes' could be used to the seaweeds used for its manufacture. The most important agarophyte genera includes Gelidium, Gracilaria, Pterocladia, Acanthopeltis, Eucheuma, Gigartina and Hypnea. A critical defination of agar is not possible at present, because it is prepared from a number of different algae and its composition varies. A tentative definition has been put forward by Tseng (1945a) as follows. 'The dried amorphous, gelatine like, non nitrogenous extract from Gelidium and other agarophytes, being the sulphuric acid ester of a linear galactan, Insoluble in cold but soluble in hot water a one percent solution of which sets at 32 - 39 C to a firm gel, melting at 80 -100 C being composed of a neutral, partially methylated polysaccharide (agarose) and sulphric acid ester (agaropectin) of a linear galactan.

The algae for agar agar extraction are gathered from rocks between mid and low-tide marks, with long handled lakes in shallow waters and by divers from the sublittoral with use of goggles. It has been suggested that fences should be built along the shore near low water mark in order to catch the weed coming a shore when the plants break off and so prevent it being burried by sand uses of Agar.

The uses of agar are manifold but probably its most important include the following:

(i) Use in bacteriological and fungal culture work, because after nutrient materials have been added even a dilute solution sets to a firm jelly upon which the bacteria or fungi can grow. The melting point of the agar is of greatest importance and for this reason the material produced from some of the Rhodophytes is unsuited for this type of work. Bacteriological agar remains liquid when cooled to 42 °C and hence organisms can be thoroughly distributed within it at a temperature which will not hurt them. It also remains a firm gel at 37 °C which is the temperature commonly employed for incubating bacterial and fungal cultures.

Another reason why it is so valuable for bacterial cultures is that it resists liquefaction eg. many bacteria convert solid media such as gelatine into a liquid solution. However some agar digesting bacteria have been isolated from marine habitats.

(ii) Use in the transport of preserved cooked fish, which is protected from breakage by being embedded in the firm jelly.

(iii) An industrial use of agar is in the sizing of fabrics but as it is much in demand the finest grades of agar are only used for the valuable silks, whilst poorer grades can be used for muslin whereas the the poorer qualities of agar are used as a coating in paper manufacture, water proof paper.

(iv) Used as a lubricant in the hot drawing of tungsten wire for electrical lamps; a suspension of powdered graphitic in agar gel is used.

(v) Used in photographic industry for making plates and films.

(vi) Employed to a considerable extent in the finishing process of leather manufacture inorder to impart a gloss and stiffness.

(vii) It is sometimes a constituent of high grade adhesive and as such is used in the manufacture of plywood.

(viii) In cooking, it is invaluable for thickening soups and sauces whilst considerable quantities are used for making frust jellies because it is more economical than gelatine and sets readily.

(ix) Its use in food products is primarily associated with its tolerance to high temperature. Thence it is widely used in Europe and America as a thickening agent in the manufacture of Ice cream, malted milks, Jelly and candies. In the preparation of ice creams and cheeses, its function is mainly that of a stabilizer and to give smoothness.

(x) It is extremely useful as roughage.

(xi) An important use in western countries is in connection with the brewing of beer and the manufacture of wines and coffee where the agar is used as a clarifying agent.

(xii) It also finds use as a pill and suppository excipient, as a base in shoestains, shaving soaps, cosmetics and hand lotions.

(xiii) There is one use of agar in wartime, this is in connection with wound dressings because agar contains a principle that stops blood clotting and thus enables wounds to be properly cleansed.

(xiv) It is also used in the making of moulds required by those who model in plaster of Paris. An extension of this usage is as a mould for the casting of artificial legs.

(xv) Other uses are as a raw material in making linoleum, artificial leathers and silks, as an insulating material against sound batteries for submarines.
No really suitable substitute for agar has so far been produced chemically and agar manufacture from Rhodophytes, seems likely to continue for many years to come.

6. ALGIN AND ALGINATES.

In seaweeds the algin is present as a mixed salt of Sodium and/or Potasium, Calcium and Magnesium. The exact composition varies with algal species. Alginic acid is found only in Brown seaweeds. There has been considerable debate as to the actual site of algin in algae, until recently the intercellular Mucilage has been regarded the principal site but there is clear evidence that it occurs also in the cell walls. Some of the algae rich in alginic and alginates include <u>Fucus</u> <u>Vesiculosus</u>, <u>Laminaria</u>, <u>Ecklonia</u> and <u>Ascophyllum</u>, <u>Sargassum</u>, <u>Turbinaria conoides</u>, <u>Turbinaria</u> <u>ornata</u> <u>ornata</u>

<u>Uses of Alginates and Algin</u>.

(i) The soluble salts especially the sodium salt of alginic acid are used in the textile industry because they form an excellent dressing and polishing material.

(ii) The soluble alkali salts can also be used as a thickening material for colours that are employed in printing fabrics and as a hardener and adhesive for joining thread in weaving. They are used alone or mixed with starch or tragacanth gum.

(iii) Another use for the soluble salts is as an adhesive in the manufacture of briquettes especially those made from brown coal or lignite, and for this purpose they are said to be markedly superior to other substances. Other possible uses are dependent upon the emulsifying power of the salts eg. in case in emulsion paints.

(iv) In the paint industry its chief functions are in:
- (a) Suspension of the pigment
- (b) Stablization of the emulsion
- (c) A better flow to the paint
- (d) Providing a continuous film to the painted surface
- (e) Giving a better coverage

Paints mixed with algin are also unaffected by wide variations in temperatures.

(v) When soluble salts have been converted into insoluble salts, the latter can be used for the production of waterproof cloth such as tents and wagon covers particularly ammoniated aluminium alginate because it becomes insoluble after drying.

(vi) Because of their pliability whilst moist, the insoluble salts can also be employed in the preparation of plastic vulcanite fibre, Linoleum and imitation leather.

(vii) Insoluble salts are used in the clarification of sugar solutions and mineral waters.

(viii) Copper and mercury alginates are said to be valuable components of paints for use under the sea because of their insoluble character. Generally all the insoluble heavy metal salts can be dissolved in Ammonia and when the solution is evaporated a water proof film is left that can be used as a varnish.

(ix) Alkaline algin especially in USA is used as a stablizer to give smooth body and texture to ice cream and preventing coarse crystals being formed, also in as suspending agent in milk shakes.

(x) Algin is used as a latex creaming and stabilizing agent in the production of rubber from natural sources but Ammonium alginate has been found the best.

(xi) A more important potential usefulness for algin can be visualized in the production of artificial fibre. If the purified alkaline extract is forced through a fine aperture it forms a viscous thread, which can be spun in a bath containing a mixture of furfurol, caustic soda, formalin and other substances. Unfortunately, threads prepared from alginic acid, sodium alginate and calcium alginate are readily dissolved by soap and soda.

(xii) It has extensive uses in medicine and dentistry

(a) Manufacture of greaseless lubricating jellies.
(b) Suspending or stabilizing agent in a number of pharmacetical prepations.
(c) Like agar, can be used as a binding material production of pills and pastilles and for emulsifying the petrolatum base of sulphanilamide ointments.

(xiii) Most useful seaweed product in the cosmetic industry
- Creams jellies, hairsprays, hair dyes.
- dispersal agent in shaving soaps and hair shampoos.

(xiv) Other uses may include
- Clarifying beer or as a water softener.
- Utilized for bleaching and washing.

Mannitol- sugar alcohol in brown algae in the sap of Sargassium sp, Fucus, Laminaria, Ecklonia sp.
Used mainly in pharmaceuticals (tablets, diabetic food) paints, leather and in preparation of lacquers, whilst plastic products obtained from it are said to be better than those from Glycerine. Used also in bacteriological cultures.

7. ALGAE IN MEDICINE.

From historical times seaweeds have been employed for medicinal purposes but it has been difficult to prove that any effect is, infact due to substances in the algae. Most of the algae are used in the form of drugs but there is at least one surgical use, short pieces of stems of Laminaria are employed in surgery for widening fistulae and wound entrances. This use is of course based upon their large swelling capacity when moistened. A number of seaweeds have been named to be useful in cases of lung disease and Scrofula eg.Gelidium sp and Dictyopteris. A species of brown alga genus Sargassum (S.linifolium) is said to be used in India in cases of bladder disorder.

8. FUCOIDAN {FUCOIDIN}.

A calcium salt of a carbohydrate ethereal sulphate. The species include Ascophyllum, Ecklonia, Pelvetia and Laminaria which produce this product.

9. LAMINARAN.

Mainly from Laminaria and Fucus. Used in Therapeutical significance as an anticoagulant. Grape sugar can be readily prepared by acid hydrolysis.

10. CARRAGEENAN.

This is a hydrocolloid. Generally employed for their physical functions in gelation, viscous behaviour, stabilization of emulsions, suspensions and foams, and control of crystal growth some of the algae genus rich in carrageenan include Hypnea and Eucheuma.

MARICULTURE OF SEAWEEDS.

The growing of marine algae in artificial environment often enriched by the addition of nutrients is referred to as Mariculture. Mariculture is aimed at increasing the biomass, yield per substrate area and achieving this under controlled or uncontrolled conditions. So far mariculture efforts have followed two distinct paths.

(a) The culture of macroscopic algae eg. Eucheuma in Tanzania, Gigartina, Hypnea, Chondrus for direct commercial use.

(b) The culture of planktonic algae for use as food for herbivorous animals eg. Shrimps and Oysters.
The culturing could be in tanks, nets; substrates etc.

PRESERVATION.

When collecting at any locality has been completed the specimens should either be pressed directly as fresh material or be preserved as quickly as possible to prevent unnecessary deterioration. Seawater should be brought up in bucket and mixed with commercial 40 per cent formaldehyde to obtain approximately 3 per cent solution. The various plastic bags into which specimens have been separated may then be partially filled with the preservative and tied. These bags, together with bulkier materials, as well as small bottles or vials of specimens, may be placed in the can in preservative and provided with an appropriate label made from 100 per cent rag paper that will not decompose in the liquid.

Of utmost importance in the preparation of any collection is the provision of adequate field data in the field collection notebook and careful preparation of labels. For this purpose, all pertinent observations on the character of the habitat, size and aspect of the various dominant species, the major associations that may be recognized, and such factors as water temperature, substrate type and exposure, should be Incorporated in the permanent book of field notes in which a consecutive series of collection numbers is tabulated later as each species is recognized sorted out and recorded.
The specimens from individual collecting bags may first be dumped into the sink and washed to remove the excess formalin. They should then be separated into jars, each species receiving a number that is listed with a tentative identification on the field data sheet. For Herbarium purposes, the algal specimens should ultimately be mounted on standard eleven and a half inch by sixteen and a half inch herbarium paper, whole sheets or suitably sized pieces of this all rag paper may be used for the next step which is the backing of the specimen as it is floated out for drying. Mounting may be best done in a flat sink, or in

a broad, shallow tray large enough to accomodate a full size herbarium sheet. The sheet of paper to be used in each instance should first be given its collection number and then immersed in the water in the bottom of the tray. The water should be of the least depth suitable for floating out the particular specimen at hand and spreading it on the paper. After the plant has been spread out in a natural manner on its backing sheet in the water to drain of gradually and to leave the specimen spread out undisturbed. The sheet or card bearing the spread specimen is then placed directly on a dry felt in the press and covered either with a piece of cloth or a sheet of ordinary waxed paper. Cloth will serve best for drying coarse, succulent specimens, but waxed paper will prove more satisfactory for smaller forms and especially for very lubricous or mucilaginous ones.

Exceedingly coarse specimens need not be spread on paper at all, but arranged between cloths, news papers or waxed paper in the press. After drying, they may be mounted on the herbarium sheets by means of straps or small spots of glue.

When the spreading has been completed and the last felt drier has been placed over specimen, the press should be strapped with the application of moderate pressure. It is necessary to prevent the specimens from shrinking or curling during the drying process and to accomplish the drying in the shortest possible time by frequent changing of the driers (at least once a day). The specimens should not be subjected to heat, as by placing the press in an oven, rather, they should be dehydrated by frequent replacement of the wet driers with warm, dry ones.

8. FISH RESEARCH

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8.1. THE PHYSIOLOGICAL RESPIRATORY ADAPTATIONS OF OREOCHROMIS NILOTICUS L.

Omollo and B. Kidi Okoth

INTRODUCTION

Most organisms are dependent on oxygen for their survival, yet many live in habitats that subject them to periods of hypoxia or anoxia. Some of these, use anaerobic metabolism to fuel short bursts of intense muscullar activity, when aerobic processes can not meet their metabolic demands. Other organisms such as those found in the intertidal regions, are subjected to variable periods of hypoxia while many endoparasitic organisms can survive indefinately without oxygen, perhaps not even using aerobic processes to generate ATP in the presence of oxygen.

The main objective of this work was to investigate physiological respiratory adaptations of *Oreochromis niloticus* to hypoxia under different temperature conditions.

This African cichlid is widely distributed around the world where temperature is suitable for its growth and reproduction. In many countries it was introduced for vegetation control, pond culture, recreational and commercial fishing, because of its excellent aquaculture potential, fast growth, omnivorous feeding habit and tolerance to low water quality. Like many other cichlids it is also known for its tolerance to temperature variations. However, from the physiological, ecological and economical points of view, such important aspects like rate of thermal acclimation, temperature acclimation, critical temperature and oxygen pressure still remain to be elucidated.

METHODOLOGY

Fish acclimatization to different temperature and oxygen tension

Live *Oreochromis niloticus* were bought from a local commercial fish stock imported to Belgium (Tihange) by Phillipart.

The fish were kept in filtered well aerated water at 25 °C for two weeks before experimentation. The fish were then transfered into the test aquaria of different temperatures (15 °C, 25 °C, and 35 °C). For each temperature, there were two aquaria with filtered dechlorinated wate, one with well aerated water (control, 9 ppm), and in the second aquarium the oxygen concentration was maintained at 2 ppm, by means of a two way magnetic valve connected to an oxygen electrode immersed in the aquarium. The magnetic valve by opening and closing controlled an input of compressed air into the aquarium. After 30 days it was assumed that the fish were acclimatised to the prevailing conditions. Fish were starved for two days prior to the experiments.

For each temperature the experiments were also carried out on fish put in hypoxia (2 ppm) for 4 hrs, 12 hrs and 24 hrs.

Respiration measurements

A simple respiration measuring apparatus (E. Verheyen et al. 1985) was used. Two respiration chambers were used, one for the blanc run and the other for the experiment. Respiration was measured at the acclimation temperature under respiration chamber one hour prior to measurments.

ANALYTICAL METHODS

(1) Tissue sampling

Unanaesthetised fish were killed by immediate decapitation. The tissues were dissected out as quickly as possible in the following order: Blood, Heart, Liver, Red muscle and White muscle. To stop all enzymatic activity the dissected tissues were frozen immediately in a liquid made up of 97.75% Absolute ethanol, and 2.25% Oleic acid at -10 °C.

(2) pH measurements

Blood for pH and oxygen affinity measurements was collected in heparinised capillaries.
The pH of the whole blood was measured with an Ingold CH-8902 pH meter.

(3) Hemoglobin concentration

Hemoglobin concentration was determined spectrophoto-metrically in its Cyan-met form. 20 µl of whole blood was collected and immediately suspended in 5 mls. drabkins reagent. After 10 minutes the absorbance was measured at 540 nm.

(4) Determination of Hb-Oxygen Affinity

Oxygen affinities of whole blood was measured by the method of Powers et al (1979), using a Hem-O-Scan oxygen dissociation analyzer (Aminco).

(5) Hematocrit determination

Hematocrit values were determined by collecting blood in microhematocrit capillaries and centrifuging at 3.00 rpm. for 10 minutes.

(6) Preparation of the tissues samples and the determination of Organic acid concentration.

The frozen tissues were homogenized by Ultra-Turrax homogenizer at 20.00 rpm, after which they were centrifuged in a refrigerated centrifuge (Sorvall RCS) at 15.000 rpm for 30 minutes. The supernatant was kept and the pellet resuspended in 1 ml. absolute ethanol. It was again centrifuged for 15 minutes at 15.000 rpm. The supernatant were pooled together, dried with nitrogen and passed through a pre-column. The analysis of the carboxylic acids were done with HPLC (Aminex HPX 87 H column).

(7) ATP assay

150 µl of whole blood was immediately suspended in 6 ml. cold 0.9% NaCl. in 10 uM phosphate buffer pH 7. 2 ml of this solution was centrifuged at 5.000 rpm. for 5 minutes in the cold. After removing the supernatant the red cells were lysed by adding 1 ml. of cold 0.75 N HC104 and centrifuged at 10.00 rpm. for 10 minutes. The supernatant is carefully removed and kept. To the pellet is resuspended in 1 ml. 0.75 N HC104 and centrifuged again. The combined supernatant was neutralized with 1.58N K2CO3 at 0 °C for 24 hrs. It was then stored at -70 °C.

Frozen samples were allowed to thaw at room temperature. 300 µl of the sample was diluted to 1200 ul with glycylglycine buffer. The firefly luciferase assay for ATP was employed for the determination using a Lumacounter T.M. 2080 apparatus. 200 µl of sample was injected into a small reaction cuvette containing 100 µl of luciferase solution (1 mg/ml in buffer). The luciferase solution was prepared from a firefly lantern extract (obtained from Sigma chemical company).

(8) Zinc measurements

Zinc was determined by Graphite Furnace Atomic Absorption Spectrophotometry.

Atomic absorption measurements were made with a Perkin-Elmer model 703 spectrophotometer, equipped with an HGA-500 graphite furnace, deuterium arc background corrector, AS-1 autosampler, and PRS-10 printer sequencer. Pipetted sample volumes were 10 or 20 l. Argon was used as the sheath and purge gas throughout. A single-element intensitron hollow cathode lamps were used for the determination of zinc. A Hewlett-packard 120 1A storage oscilloscope was used for registration of atomic absorption and background signals.

Ultrapure nitric acid (UCB) was used for sample digestion. 1000 l of whole blood suspended in 6 ml. cold 0.9% NaCL in 100 M phosphate buffer pH 7.0 was centrifuged for 15 minutes and was then ready for determination. Concentrated blood samples were dissoluted by Microwave aided nitric acid digestion and diluted with water.

(9) Measurements of glycogen concentration

Glycogen was determined by homogenizing the tissue in 3 ml. bicarbonate buffer pH 9.5. To 1 ml. of the homogenate was added 1 ml. 30% KOH, then uncubated at 60 C for 30 minutes , after which it was neutralized by the addition of 1 ml. 5N HCl. 1 ml. 40% TCA was added to this solution and was centrifuged for 10 minutes at 20,000 rpm. To 1 ml. of the supernatant was added 50µl Na2SO4 and 3 ml 96% absolute ethanol. This was then incubated in a water bath at 90 C for 30 seconds, afterwhich it was cooled in ice at 0 °C for 15 minutes, then centrifuged for 30 minutes t 20,000 rpm. The supernatant was decanted and tubes left to dry for 5 minutes . The pellet obtained was dissolved in 2 ml of distilled water. To 200 µl of this solution , 3 ml Anthron reagent was added and incubated for 20 minutes in a water bath at 90 °C. The solution was allowed to cool at room temperature.

The absorbance was read at 620 nm.

RESULTS.

General Observations.

Relative to the normoxic fish, the hypoxic fish were clearly under stress during the first week of acclimation. These fish attempted to breath air at the surface and operculated rapidly to facilitate the uptake of oxygen. They did not eat as readily as their normoxic counterparts. Their behaviour during the third week of acclimation was however strikingly different. The fish no longer remained at the surface and they operculated at a relatively normal rate. They were just as active as normoxic fish.

Respiration.

In normoxia acclimated fish we find that there is no clear difference in oxygen uptake at temperature 25°C (117 µg/g/hr) and 35°C (123 µg/g/hr), but there is significant difference at 15°C, where the oxygen uptake is much lower (68 µg/g/hr). The oxygen uptake of hypoxia acclimated fishes compared to normoxia acclimated fishes does not show any difference at temperature 15 °C. At 25°C the hypoxic fish have slightly higher oxygen uptake and this difference is even greater at 35°C where the oxygen uptake of hypoxia acclimated fishes is more than double that of the normoxia acclimated fish (fig.2).

Blood-oxygen affinity

Oreochromis niloticus, acclimated to hypoxia displays a striking increase in blood oxygen affinity as compared to normoxia acclimated fishes. The P50 increased with increase in temperature even for normoxia acclimated fishes. The blood of fishes subjected to acute hypoxia (short period in hypoxia), also showed an increase in oxygen affinity. For each experimental temperature, the P50 of fish subjected to hypoxia was significantly lower than that of the normoxia acclimated fish. For the fish subjected to short period of hypoxia, we observed a sudden drop in P50 (fig.1).

The P50 for the fish subjected to 12 hrs hypoxia was lower than that of those subjected to 4hrs hypoxia. Then there was a gradual increase in P50 of fish subjected to 24hrs hypoxia, which shows that the fish was getting acclimatised to hypoxia. Fig.3 shows critical oxygen tension, which is higher in the normoxia acclimated fish at 15°C and 35°C, but lower for the hypoxia acclimated fish.

The blood pH

The blood pH of the fish subjected to a short period hypoxia was more acidic than those of the above two, due to an increase of the production of the carboxylic acids (table 1).

The hemoglobin concentration of hypoxia acclimated fishes was higher than that of the control fishes except at 35°C where there seems to be no difference (table 2).

Hematocrit results are more or less the same, which could suggest that there was no increase of red cells, but just an increase of hemoglobin concentrations in the cells (table 3).

ATP concentration of hypoxia acclimated fishes was less than that of the normoxia acclimated fishes (table 4).

In the hyppoxia acclimated fish glycogen concentration dropped with an increase in temperature, while the glycogen concentration in the muscles was the same (fig.4).

The hypoxia acclimated fish had a low concentration of zinc in the hemoglobin (fig.5).

Lactic acid is the main end product of glycolysis in the red and white muscles. The level of organic acids in the tissues of hypoxia and normoxia acclimated fishes is the same.

DISCUSSION

The oxygen transport function of the blood, is more or less the product of a complex integration of the effect of various physiological factors (temperature,concentration of dissolved gases, allosteric cofactors protons and other ions,on the oxygen binding properties of hemoglobin. Changes in their concentrations correlate neatly with adaptive modulation of blood oxygen affinity in teleost in response to changed environmental or metabolic stimuli. Thus an increase in oxygen affinity permits a high oxygen uptake by prebranchial blood at the gill and thus an adequat supply of oxygen to the tissues despite a reduced oxygen tension. This is evident to our results (fig.2), where the P50 of the hypoxia acclimated fishes were much lower than that of the normoxia acclimated fishes and also the P50 increased with increase in temperature, D.Suze G. et al (1985) working on *O.niloticus* observed that while the P50 of the whole blood changed between hypoxia and normoxia, the P50 of the purified hemoglobin remained the some, therefore it can be said that the difference in whole blood P50 values is not due to a change in the hemoglobin molecule, but must result from a difference in the intracellular enviroment.

The change in pH of the hypoxia acclimated fish is small (0.27), see Table 1 but it is significant in relation to its effect on hemoglobin, oxygen affinity i.e. this difference via the Bohr effect could contribute to the observed difference in the P50. The blood acidosis observed with the fish subjected to short periods of hypoxia was due to the fact that these fishes upon suddenly being subjected to hypoxia turn to anaerobic pathways to meet their energy demands and therefore there is a lot of inorganic acids produced as end products. This acidosis gradually decreases because the fish by lowering their metabolic demands can turn to aerobic processes. This is clearly indicated in our acids in the tissues of hypoxia and normoxia fishes is the same.

The increase in hemoglobin concentration of the hypoxia acclimated fishes (table 2), can be said to be a compensation to hypoxia by increasing the oxygen delivery to tissues and thereby reducing the cardic output required for a given respiration.

Hematocrits of hypoxia acclimated fish was higher and this is an adaptation, to increase the oxygen carrying capacity of the blood (table 3).

The ATP results, (Table 4) obtained agree with those of other workers, who showed that ATP and GTP in normoxia acclimated fish is higher. ATP and GTP have been shown to play a dominant role in adapting oxygen affinity to such environmental conditions as oxygen tension or temperature, Gillens and Riggs (1977), Wood and Johansen (1972).

The existence of thermal adaptation and changes in metabolism as a result of alterations in the thermal environment is a well established phenomenon in nature. In many animals oxygen consumption varies with oxygen tension and temperature. During the period of hypoxia the oxygen consumption of the animal decrease relative to the pre-hypoxic period. The hypoxia acclimated fishes, especially at 35 °C (fig.1) had a higher oxygen uptake than the normoxia acclimated (control) specimens. This can be explained by the fact that during the period of hypoxia, the oxygen consumption of the tested fishes decreases relative to the pre-hypoxic period. An oxygen deficit or debt then exists. When the animal returns to normal oxygen levels, this debt is paid back i.e. the oxygen consumption becomes higher than its pre-hypoxic rate. The oxygen uptake of the hypoxia acclimated fishes at 15 °C is the same as that of the control specimens at the same temperature. It is clear, therefore that contrary to specimens tested at higher temperatures, these hypoxia acclimated fishes at 15 °C do not experience an oxygen deficit. As temperature increases the difference in oxygen uptake between hypoxia and normoxia acclimated (control) fishes increases.

Lactic acid is the main end-product of glycolysis in the red and white muscles. Since the level of organic acids in the tissues of hypoxia acclimated and normoxia acclimated fishes is the same it can be said that the hypoxia acclimated fishes are really acclimatized so that they maintained their energy demands using aerobic pathways, provided with the necessary oxygen by an altered (acclimatized) respiratory complex (e.g. gills, hemoglobin function ...).

A remarkable reduction in glycogen content in the liver of hypoxia acclimated fishes shows that the shift from aerobic to anaerobic metabolism may cost a lot of energy.

CONCLUSIONS

Investigations on the physiological properties of the whole blood and of the purified hemoglobin are recognized as important in the evaluation of optimal survival of the species under well defined conditions.

The major changes we observed occurred in the blood. Therefore the respiratory properties of the whole blood clearly show that *O. niloticus* is naturally adapted to hypoxic waters.

We intend to publish these results in 3 papers in the near future.

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Table: 1 BLOOD pH: LONG AND SHORT PERIOD ACCLIMATION.

		4Hrs.	12Hrs.	24Hrs.
15C° Control Hypoxia	7.74±0.05 7.99 ± 0.28	7.15 ± 00		
25C° Control Hypoxia	7.51 ± 0.40 7.87 ± 0.33	7.36 ± 0.14	7.71 ± 0.14	7.71 ± 0.15
35C° Control Hypoxia	7.59 ± 0.098 7.80 ± 0.11	7.48 ± 0013	7.42 ± 0.0	7.60 ± 0.02

Table: 2

LONG PERIOD ACCLIMATION.

Hemoglobin Concentrations.

	15 C° mg/ml	25 C° mg/ml	35 C° mg/ml
Normoxia	51.08 ± 6.0	64.23 ± 2.4	57.22 ± 6.9
Hypoxia	70.64 ± 11.85	80.07 ± 2.78	52.29 ± 6.3

Table 3

Hematocrit Concentrations.

Normoxia	25% ± 1.86	22.65% ± 1.1	20.02% ± 1.92
Hypoxia	24.10% ± 5.34	26.23% ± 1.2	22.5% ± 1.3

Table: 4. ATP Concentrations in red blood cells.

mMol ATP/ml.

Temperature	15 C°	25 C°	35C°
Normoxia	394.729 ± 14.77	375 . 647 ± 33.15	283.224 ± 9.013
Hypoxia		327.939 ± 31.76	220.008 ± 7.24

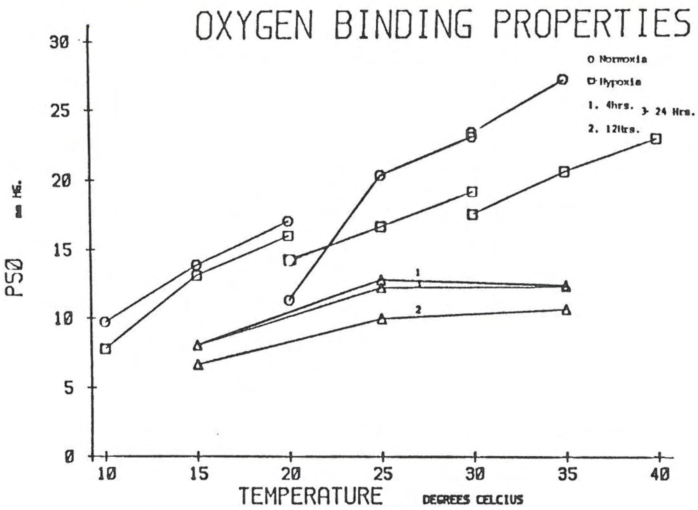
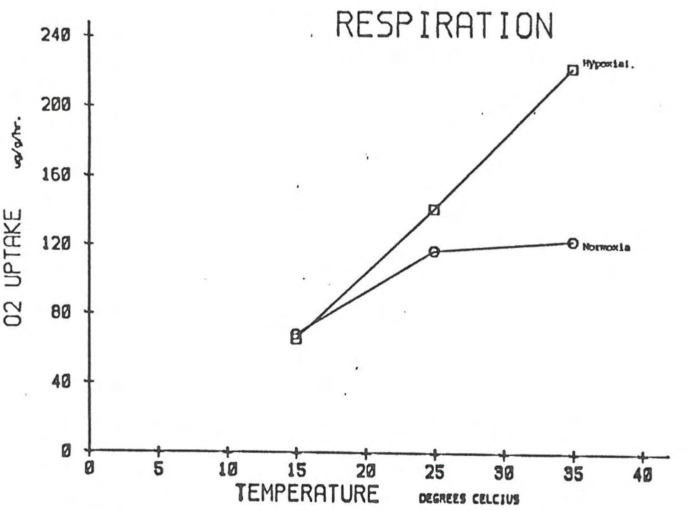


FIG. 1 LONG AND SHORT PERIOD ACCLIMATION.



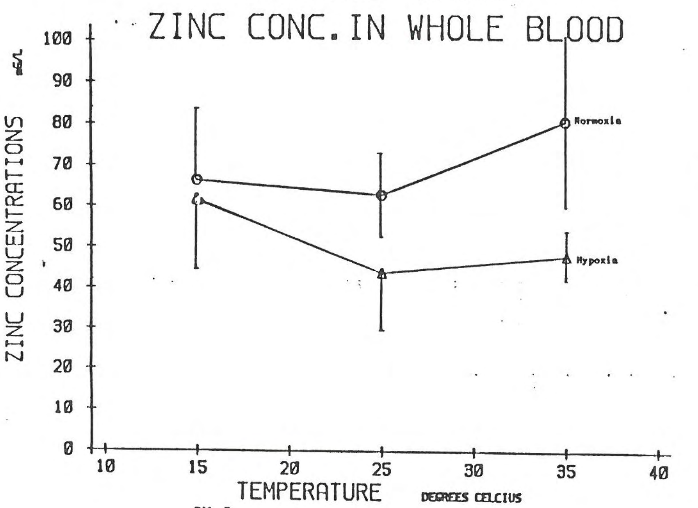


FIG. 5

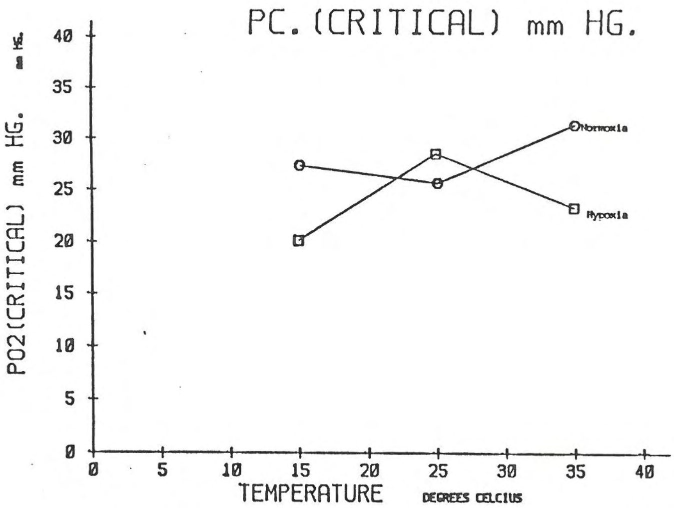


FIG. 3 LONG PERIOD ACCLIMATION.

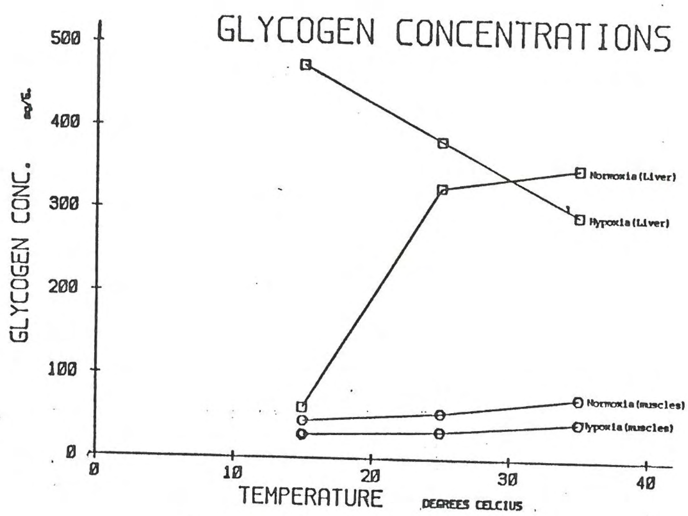


FIG. 4 Long period acclimation.

8.2. IMPROVED UTILIZATION OF NILE PERCH. OVERALL CHANGES IN TOTAL VOLATILE BASES; ACID VALUE (FFA) AND ORGANOLEPTIC ASSESSMENT OF NILE PERCH STORED IN ICE AND AT AMBIENT TEMPERATURE

P. Oduor

INTRODUCTION

Spoilage of fish starts immediately it is out of water. Fish stored in ice spoils as a result of bacterial and enzyme action which results in the formation of volatile bases.Total volatile bases released is used as an indication of spoilage of fresh waterfish. In case the fish is fatty like the Nile perch, an increase in the acid value due to hydrolysis of fat is also used as an indicator of spoilage. Organoleptic assessment of the fish is used as visual gauge for spoiling fish and is even more useful if related to acid value and TVB value. Accepted TVB values ordinarily are below 20 mgN TVB/100g of fish beyond which fish are considered stale and acidity values of 0.5 - 1.5% are noticeable to the palate.

SUMMARY:

Quality score (Q.S) for the fish were daily recorded. The same applied to fish stored at ambient conditions.

The Q.S. after 2 weeks was still above neutral hence the fish were still acceptable and Q.S. for fish stored at ambient conditions dropped below acceptability line around 17 hours. Acid value and TVB values for the fish stored in ice did not go beyond acceptable values. However, Acid value and TVB values for fish stored at ambient conditions rose fairly and agreed with Q.S. from organleptic assessment and hence became unacceptable.

METHODOLOGY:

Fish were brought from board and stored in ice boxes packed with ice in the cold room and daily assessment of the quality score of the fish carried out organoleptically. Acid value and TVB value analysis also carried out, temperature of cold room and of fish being recorded as well. Organoleptic assessment was based on a scale as below:-

0	4 - 6		9
Rejected Unfit for human consumption	neutral 2nd class	1st class fish, good	very fresh fish

Compiled by judges (among the research team) with Q.S. of 6 considered neutral and a Q.S. below 4 considered unfit for human consumption. The organoleptic parameters looked at were the eyes, gills, skin, scales, texture, gill oduor etc. same applied to fish stored at ambient conditions.

The Conway-micro-diffusion technique was used for the determination of total volatile Bases.

For free fatty acids (Acid value) the extraction was done using the soxhlet method and fat extracted dissolved in ethanol and diethyl ether for titration with NaOH. (Pearsons J.D. 1981).

RESULTS.

The results for the organoleptic Q.S.; Acid value, TVB value for both fish stored at Ambient temperature and in ice are tabulated below:

DISCUSSION:

TVB value of fish considered to be fresh is 20 mgN/100g a figure of 30 mgN/100g, the fish is regarded as stale. Above 40 mgNTVB/100g the fish are considered unfit for human consumption. (Lang 1979) Acidity begins to be noticeable to the palate with values of 0.5 - 1.5% FA expressed as oleic acid (Pearson J. D. 1981).

The TVB value for the Nile Perch analysed ranged between 6.00 mgN/100g upto about 20 mgN/100g against the Q.S. of the fish, despite the 30mgN/100g mark the fish was actually below Q.S. 4 hence rejected. I would suggest that the TVB for Nile perch is generally lower than the scale set of 30 mgN/100g because at that value alone organoleptically the fish is completely spoilt.

For acid value expressed as oleic acid, there is not much variation with storage time in ice except Q.S. of fish stored in ice up to 10th of June showed a fair correspondance with a fairly high acid value of 0.9024. Getting guidance from an ambient storage, the acid value rose drastically from 2200 hours almost corresponding to the rise in TVB and fall in the Q.S.

It would be difficult to suggest a chemical value of TVB/Acid value for Nile perch but if we look at the ambient storage the Q.S. showed actually that the fish were spoilt and rejected. I would suggest an upper limit of spoilage for acid value as above 1.000% and about 30 mg/N as the upper limit of spoilage for TVB value in Nile perch and work from that figure to get the actual point of spoilage by narrowing the time interval to about 1 hour because the transition point at 2200 hrs to 0400 hrs is not agreeable as the change was too drastic.

For the whole Nile perch stored in ice, it is my bone of contention that the storage life is much longer than 2 weeks because it lasted up to that level despite not being iced on board, and stored immediately. It took about 6 hours to put them finally in the cold room. The TVB for fillet followed a pattern similar to whole fish, its upper TVB limit being 22.3 mg NTVB/100g.

This project was done with a lot of contribution materially from Kenya Belgian Oceanographic project and the work was done in Kisumu.

REF: (i) J.D. Pearson 1981 (Chemical Analysis of food)

(ii) FAO Fisheries tech. paper No. 210.

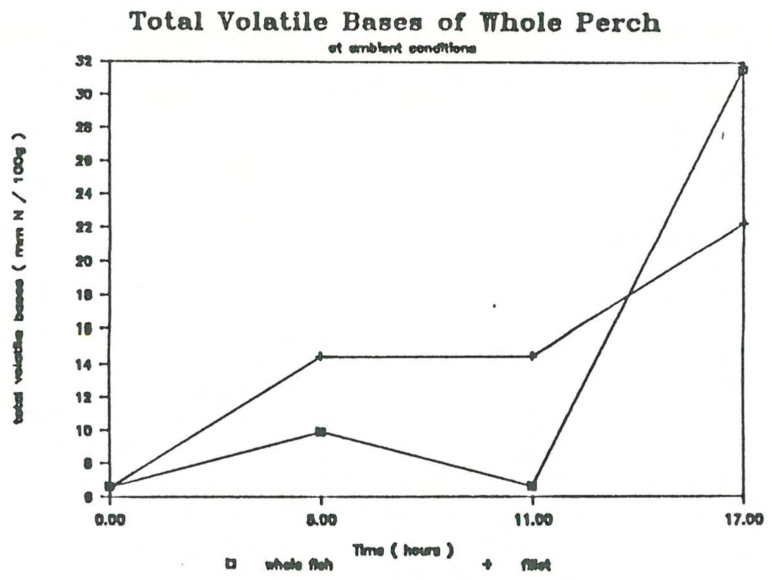
QUALITY CHANGES OF WHOLE NILE PERCH STORED AT AMBIENT CONDITIONS

HOURS	1100 HRS	1700 HRS	2200 HRS	0400 HRS
STORAGE TIME	00 HRS	6 HRS	11 HRS	17 HRS
ATMOSPH. TEMP	31-32 C	29 C	26 C	23.2 C
C of FISH	28-29 C	27.5 C	26 C	25.5 C
Q.S. of WHOLE FISH	9	9	7-8	4-3
pH of WHOLE FISH	671-5.2	6.75-5.2	6.88-5.2	6.59-5.2
TVBN mgTVB/ 100g	6.56	9.843	6.56	31.5
ACID VALUE (a) (BELLY FLAP)	0.746	4.675	5.178	11.84
LOG ACID VALUE				
LOG TVB				
ACID VALUE (c) FILLET	.197	.338	.338	1.0716

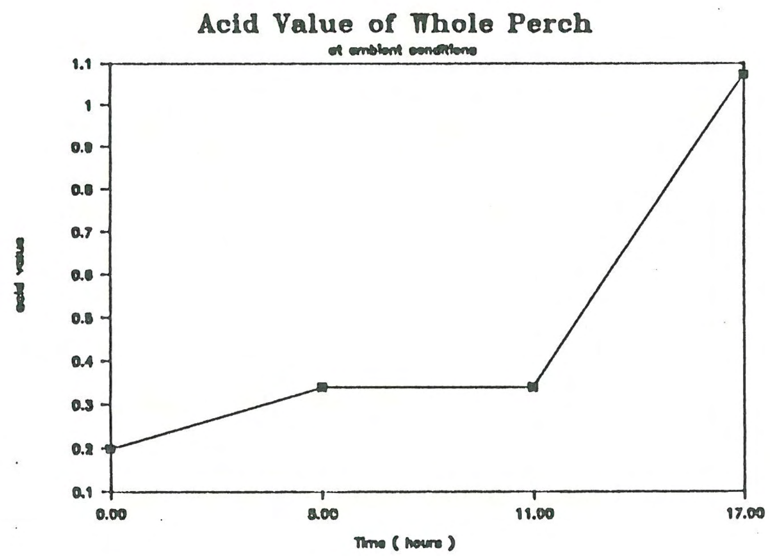
STORAGE TIME	00 HRS	6 HRS	11 HRS	17 HRS
ATM TEMP	31.0 C	29 C	26 C	23 C
C FILLET		27.5 C	25 C	23 C
PH - FILLET		6.66 - 5.2	6.65 -5.2	6.66 -5.2
TVB - FILLET	6.56	14.4375	14.4375	22.3125
LOG TVB FILLET				

Acid value (a) = Acid value = $\frac{\text{mls NaOH} \times 5.61}{\text{weight of sample}}$

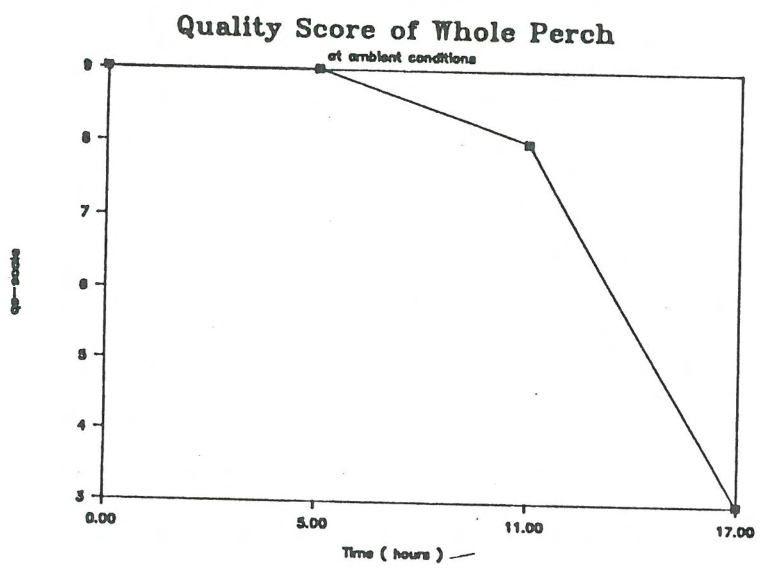
Acid value (c) 1 ml NaOH = 0.2828 oleic acid
hence Acid value = 2 x FFA



Total Volatile Bases of Whole Perch
at ambient conditions
total volatile bases (mm N / 100g)
Time (hours)
whole fish
fillet



Acid Value of Whole Perch
at ambient conditions
acid value
Time (hours)



Quality Score of Whole Perch
at ambient conditions
Time (hours)

ORGANOLEPTIC ASSESSMENT OF WHOLE NILE PERCH STORED IN ICE (^oO)

DATE	STORAGE TIME	EYES	GILLS	SKIN	SCALES	TEXTURE	GILL ODUOR	OVERALL SCORE
27-05-87	0 days	Yellow, Convex	Bright red	Brilliant mettalic	firm	Elastic, firm	fresh	9
28-5-87	1 d	Convex, clear, yellow	Red, very Little slime	Shiny metallic	firm	Elastic, springy	fresh	8-9
29-05-87	2 d	Red, Convex	Red, slimy	Dullish, dorsally dark, light ventrally	firm, some loose ventrally	Elastic, springy soft ventrally	Slighty Sour smell	6-7
30-05-87	3d	Convex, yellowish	Maroon red with some bleached patches	Metallic bright	firm, body slimy	firm elastic	smell of blood	7-8
31-05-87	4d	Sligtly reddish	Red, Little slime	Dorsally dark, ventrally light	firm, body slightly slimy	firm, elastic	smell of blood with distant odour of sea weeds	7-8
1-06-87	5d	Convex, transflùscent Light red	slimy,	metallic, bright ventrally dull dorsally	firm, very slight slime	Elastic	no off odour	7-8
2-06087	6d	Abit Convex and red	Red(Maroon) with bleached pa-tches ½ the gills slimy	Dark on dorsal side, metallic patches, yellow streaks on belly area.	A bit firm on the dorsal side, loose on the belly area	Elastic	slight smell of rotten sea weeds.	6
3-06-87	7d	Convex, clean, centre bright yellow	Red-with some slightly bleached clean slime in the Gills	Bright metallic Lustre, a few dull patches	firm	firm, Elastic	fresh no off oduor	8
4-06-87	8d	Convex, Red	Bleached, slight Yellowish slime	metallic	firm	Elastic	no off oduor	7-8
5-06-87	9d	Milky, yellow neath, convex	Bleached with red patches. slightly slimy	metallic tright	firm	Elastic, springy	Onion-gaulic tightly	7-8
8-05-87	12d	Convex, Red	Red, brown patches	metallic bright ventrally dorsally dark reddish patches ob belly	firm	Elastic, springy	Seaweeds	7-8
10-06-87	14d	Red, slightly convex	Eleached with red patches,	reddish patches or belly: brighter ventrally dark dorsally	A bit loose slimy impression Left	Finger print i impression left	off-oduor-slightly rotten smell	6

11-06-87	15d	Reddish, flat	Reddish with bleached patches, slimy	Bleached, bright ventrally dark dorsally	slimy fairly loose	finger print impression left when pressed	smell of rotten sea weeds	5-6

ORGANOLEPTIC ASSESSMENT OF WHOLE NILE PERCH STORED AT AMBIENT CONDITIONS 5-6 JUNE 1987

1100 HRS	STORAGE TIME	EYES	GILLS	SKIN	SCALES	TEXTURE	GILL ODOUR	OVERALL SCORE
1100 HRS	0	Convex, yellow	Brilliant, silvery no slime and shiny	Brilliant silvery bright	firm	firm, elastic	fresh	9
1700 Hrs	5 Hrs	Convex, yellow	Red, no slime only one bleached	dried, very sli- slightly slimy	firm	firm, (rigor)	fresh	8- 9
2200 Hrs	5 hrs	Conves, yellow, creamy	Bleached patches, slimy	Bright, metallic	'Firm'	firm, out of rigour	rotten sea weeds	7-8
0400HRS	5 hrs	Convex, Red	green with a bit reddish patches majority brownish	metallic, some yellowish	firm, slime on body around belly region	soft, finger prints remain on it	off odour rotten area?	4-3

QUALITY CHANGES OF WHOLE NILE PERCH STORED IN ICE

DATE (DAYS)	1	29th MAY	30th May	31st May	1st June	2nd June	3rd June	4th June	5th June	6th June	7th June	8th June	10th June	11th June
STORAGE TIME	1d	2d	3d	4d	5d	6d ½	7d	8d	9d	10d	11d	12d	13d	14d
°C COLD ROOM 6	12.0	11.2°C		9.8	10.9	5.7	6.3	7.3	13.2	-	-	10.4		
°C FISH [illegible]		0.5°C		1.2	0.4	2.9	0.3	0.7	0.9	-	-	0.9		
Q.S. WHOLE FISH	8-9	8-9	7-8	7-8	7-8	6	8	7	7-8	-	-	7-8	6	5-6
PH WHOLE FIHS	7.4-5.2	7.1-5.2	6.67-5.2	6.6. - 5.2	7.11-5.2	7.41-5.2	6.65-5.2	7.09-5.2	6.67-5.2	-	-	6.68-5.2	6.57-5.2	
TVB		11.8125	6.56	6.5625 / 16.406		16.40	19.03	5.25	9.843	-	-	7.875	16-76	19.320
ACID VALUE (a) (DORSAL).		3.975	10.2		8.014	2.576	7.381	-	18.7	-	-	7.0125	14.025	8.014
ACID VLAUE (b) (B/FLAP)		2.066	2.34	0.746	1.602	0.970	1.969	3.725	2.078	-	-	1.0625	2.624	5.61
ACID VALUE (C) DORSAL		.807	.2256	-	.169	.507	.282	-	.0564	-	-	.4512	.282	.592
ACID VALUE (d) BIFLAP		.3948	.5076	.197	.5076	.282	.344	.479	.282	-	-	.282	.9024	.564

9. CURRENTS RESEARCH

CURRENT MEASUREMENTS IN TUDOR INLET
Mutua M.

Water movement study in Tudor inlet, using langragian drifters, is being done with the three objectives: To increase our present knownledge on tidal currents and other currents. To relate current patterns to distribution of plankton and other marine life forms. To observe flow effects on turbidity, degree of mixing and the structure of physico -chemical gradients.

For convenient the inlet is divided into Tudor estuary, Mid-Tudor and Lower-Tudor (figure 1). The estuary is shallow with depth average of 5m and a surface area of 16 km. In Mid and Lower parts the inlet is narrow, depth average to 25m and the water is directly influenced by East African coastal current (figure 1) due to a very narrow continental shelf.

Drift measurements taken during spring-neap flood and ebb tides between January and March of 1987, indicate that the inlet, particularly in its lower reaches, is strongly influenced by tidal currents and longshore-rip systems. The tidal flow in the main channel is variable with speed range of 0.2 -1m/s. However considerable spatial and temperal variation occur. Some of these variation are shown in figure 2 and 3 which depicts some of the observed inter-tide drift speeds in lower Tudor for February 2nd and March 4th 1987. Tables I and II give data for this pattern. Longshore current is seen to the eastern shore of the channel between Ras Kindomoni and Mackenzie point. The current flows more or less permanently into the channel with speed of 0.02 - 0.2 m/s. Maximum flow occur between 1000 - 1300 hours during peak winds of 6-9m/s, suggesting that wind may play a significant role in pushing some of the water into the inlet, although tidal current predominate.

An interesting feature of the longshore current is formation of a loop which give rise to anticlockwise eddy during ebb. This eddy degenerates into a small clockwise eddy during flood tide which become trapped windward of Ras Kindomoni, one side of the little eddy merges with rip-feeders of which plume or littoral drift is entrained by the main tidal stream further in the channel. The position of the rip-head vary. During flood it occurs near Ras Kidomoni and in ebb tide off Mackenzie.

The eddy and the rip-head carry considerable concentration of floating debris and juvenile fish and appear to hold different turbidity and degree of mixing. Ebb plume associated with flow seem to suggest a mild physico-chemical gradient accross the channel. Work is still being carried out in this aspects.

TABLE 1 DATA

Langragian Drifters survey.

Location: Tudor inlet lower area.

Date: February 2, 1987. spring flood tide

Area	SITE OF STATIONS		
	Eastern shore speed m/s	Mid speed m/s speed m/s	Western shore speed m/s
Bahari Club	variable 0.02 (oceanward)	0.05 0.06 (landward)	-----
Ras Kibaramini	0.09 (landward)	0.08 (landward)	0.02 (oceanward)
Ras Kidomoni	0.1 0.1 (Towards western side)	----	0.02 oceanward variable.
	variable 0.13 (landward)	-----	-----
Mombasa old harbour	0.05 (toward cove)	0.1 (landward)	----
Mackenzie Point	----	0.1 (landward)	0.08 (longshore landward)

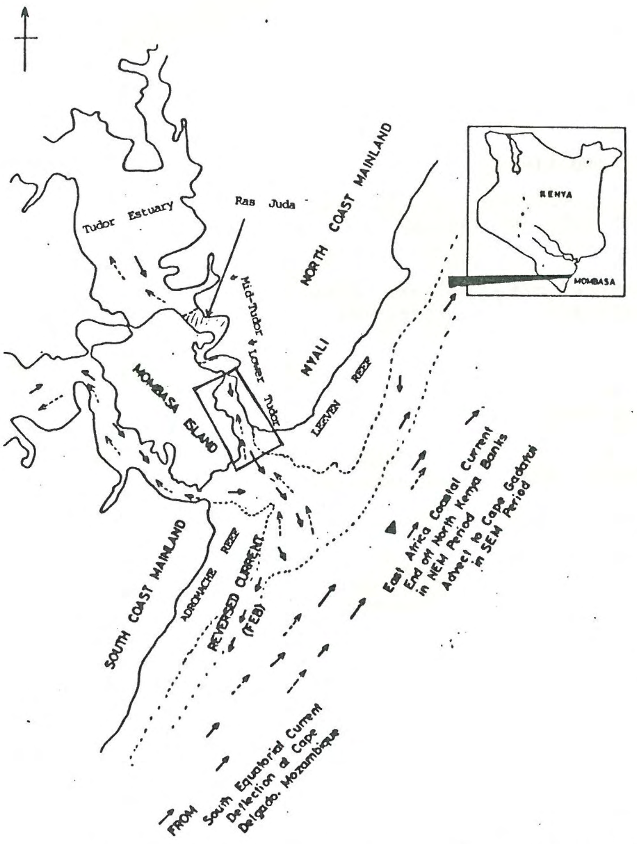
TABLE II DATA

Langragian Drifters survey

Location : Tudor inlet lowr area.

Date: March 4, 1987 Ebb

Area	SITE STATION (SPEED m/s)		
	Easternshore	Mid channel	Western shore
Bahari Club	0.01 (landward) variable	0.2 (oceanward)	-----
Ras Kibaramini	----	0.2 (oceanward)	------
(Babusi jelly)	0.01 (oceanward)		
Ras Kindomoni	0.24 (oceanward)		0.02 (oceanward)
(cove)	0.23 0.1 0.04 (landward)	0.05 0.25 0.2 (oceanward)	----- -----
Mackenzie point	0.01 0.02 (landward)	0.01 (oceanward)	0.1 0.09 (oceanward)



ure I. Schematic flow pattern for coastal water off Mombasa Island 0 1 2 3km

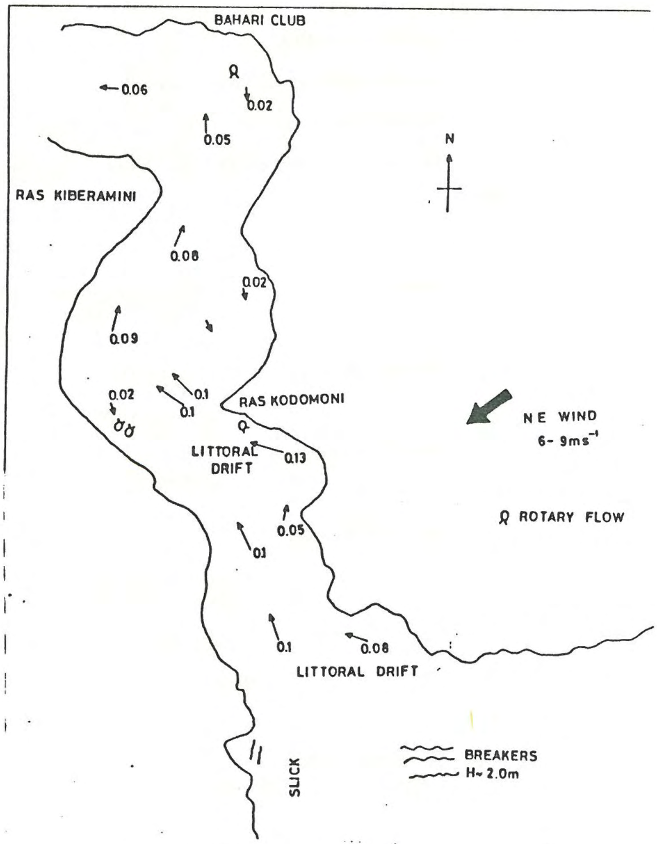


Fig. (2a). Water movement during spring flood tide in Lower Tudor inlet (February 2,1987)

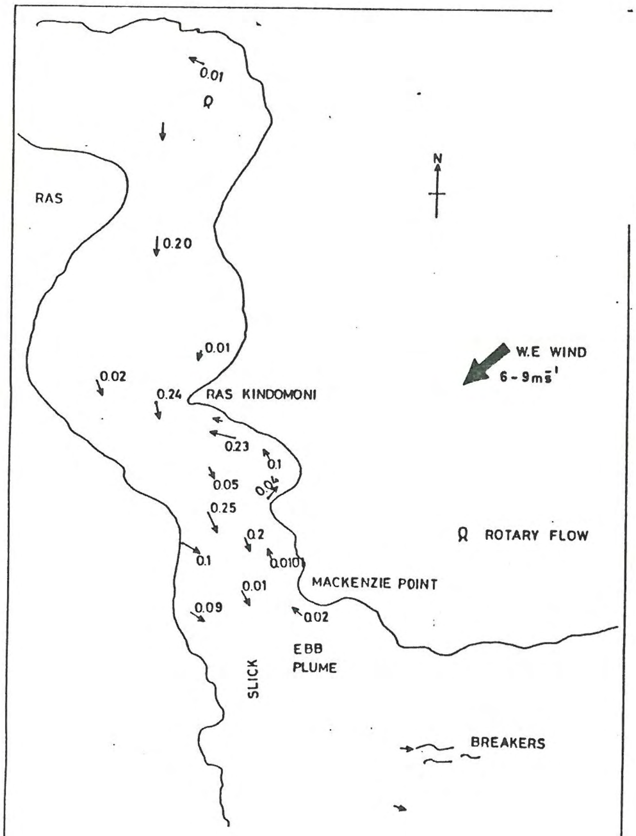


Fig.3(a) Water movement during ebb in Lower Tudor inlet (March 4,1987)

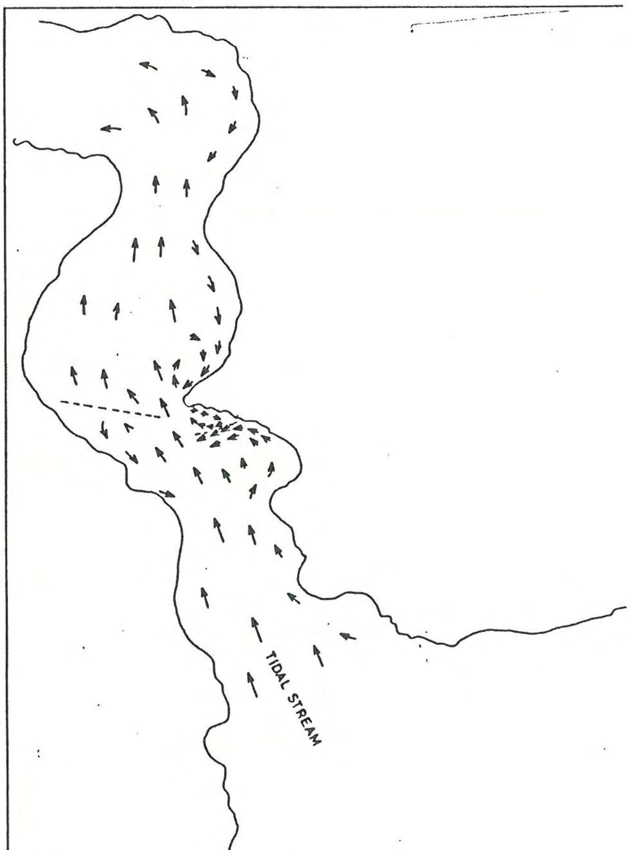


Fig. (2b). Schematic presentation of the flow features in Fig. (2b) showing rotary (Eddy) flow and longshore currents

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10. DOCUMENTATION AND COMPUTER CENTRE

10.1. PROGRESS REPORT OF THE KMFRI-KBP COMPUTER SECTION

H.Onyango & P.Pissierssens

In many Universities and Scientific Institutes, Marine Scientific Research is either planned to start or already in progress. It is however clear that most of these Institutes are facing serious problems :

- Funds for Libraries are reduced. Therefore periodicals which are essential for Research are no longer subscribed to, leaving the Scientists in a position isolated from the current progress in Scientific Research.

- Contacts between Researchers of the various Institutes are scarce and limited to Scientific Seminars and other meetings. Furthermore, Scientists of the developing countries find themselves unable to attend these meetings because of financial restraints of their Institutes.

- Contacts with UN organizations are equally limited and not always effective due to the hierarchy and following inertia of the structures.

- There are practically no coordinated Research Programmes related to Marine Sciences between the Institutes of the Region. Following this many Scientists in the Region are working on the same subjects without knowing it from each other.

To solve these problems we envisage the establishment of a Personal Computer Network in the East-African Region.

UNESCO, IOC, KENYA and BELGIUM have therefore organized a mission , funded by UNESCO to ascertain the feasibility of this network. The mission was carried out by Hezborne Onyango (KMFRI) and Peter Pissierssens (KMFRI, ABOS-UCOS volunteer) between 18/4/87 and 18/5/87.
The mission visited Institutes in several countries :

- Somalia : Somalia National University
- Madagascar : Centre National de Recherches Oceanographiques
- Mauritius : University of Mauritius
- Tanzania : University of Dar Es Salaam, Tanzania National Research Council
- Ethioipia : Asmara University
- Seychelles : FAO (SWIOP), Seychelles Fishing Authority, ORSTOM
- Kenya : KMFRI, University of Nairobi, UNESCO-ROSTA Nairobi

In these Institutions we gave information on the Project Proposal and tested the telecommunications facilities.
In the mission report " The Feasibility of a Personal Computer Network in the East-African Region for the exchange of bibliographical and scientific information" it has been shown

that the Network is technically and financially feasible with Mombasa (KMFRI) as Headquarters.
In view of these conclusions a Project Proposal will be introduced by the Kenya Government to several UN organizations and to the EEC.

10.2. EDUCATION AND TRAINING FOR ONLINE SEARCHING AND DOCUMANTATION

Mwobobia J.

70997

Education for online use of databases is concerned with the fundamental principles and basic knowledge of information science and how they relate to search strategy formulation, bibliographic databases structure, user's needs, etc. whereas training is concerned with details of specific databases and search systems, their interaction and ways of optimizing their use.

Searching is the interaction between you, the searcher, and the retrieval system. Online information retrieval is therefore, a problem solving activity requiring knowledge and understanding of the basic concepts and principles for consistently good results.

The course is designed to provide the fundamental skills necessary for effective use of online information systems. The principal objectives of the course are:-

i. General overview of online searching including the scope of the services, databases and equipments required.

ii. Detailed description of the search facilities and techniques including information about database structure.

iii. Comprehensive study of the DIALOG System: knowledge of the basic commands and the features of the DIALOG retrieva language; familiarization with the typical unit record and construction of DIALOG database; introduction to search strategey developments; instruction on terminal use and telecommunication protocols; hands-on practice including basic commands, sample searches, procedure for logon and logoff.

iv. Computer for information management: Computer is a working tool, by nature of the work of an information centre, computer and the all-important software that instruct the hardware, is useful for cross references, eg. CDS/ISIS (Computer Documentation System/Integrated Set of Information System).

v. Training and search strategy on CDROM {Compact Disk Read Only Memory) Coverage of ASFA database on CDROM.

11.1. KENYA'S COASTAL FISHERIES: ARE THEY UNDER OR OVEREXPLOITED

T. McClanahan and N. Muthiga

One often hears contradictory statements about the potential of Kenya's coastal fisheries resources. Some state that the coastal fisheries are underutilized and through increased effort could produce additional food and economic resources. Others argue that marine resources are being overexploited and long-term negative environmental damages are likely to occur from this exploitation. The management implications of each arguement are quite different and the outcome of following them could either result in the underutilization of marine resources or environmental degradation from overexploitation. How then can these seemingly contradictory viewpoints be reconciled into developing a long-term management strategy for Kenya's coastal fisheries?

The clarifying distinction in this debate is the difference between inshore and offshore fisheries. Inshore fisheries occur close to shore and therefore fishermen can easily travel to and from in a single day, whereas offshore fisheries occur at greater distances. The economics of exploiting these two areas are quite different and subsequently fishing pressure will differ. The majority of Kenyan fishermen lack sufficient capital to buy large power boats with refrigeration facilities that would allow exploition of offshore fisheries. Therefore, most fishing effort is focused on inshore areas. Additionally, fishermen often adapt their effort to demand and therefore focus fishing effort in areas close to population centers. The result is that areas close to markets are heavily exploited while areas further away are less exploited. The introduction of ice and refrigerated boats and trucks in the last few decades has allowed areas further away from markets to be exploited. Yet, the net result of this exploitation is a spatial inequality in fisheries resource use. The inshore areas being exploited while offshore areas were underutilized. Additionally, some inshore areas near population centers are heavily exploited and subsequent long-term losses of fisheries productivity and associated environmental problems are likely to occur.

During the course of our research along Kenya's coast we investigated the effects of fishing and shelling activities on the coral reef's community structure, potential long-term productivity and ecosystem functions. Results indicate drastic changes as fishing and shelling activities increase. The primary difference being that as fish densities and sizes decrease due to increased fishing effort there is a proportional increase in sea urchins. In particular the burrowing sea urchin *Echinometra mathei* which appears to increase proportional to a decrease in predators. A problem arising from their increase is that though their feeding and spine abrasion activities they reduce live coral cover and increase substrate bioerosion. The result is a loss of live coral, the reefs complexity and refuge which corals supply to many coral reef fishes. Additionally, in the absence of sea urchin predators, sea urchins may utilize algal resources that might otherwise feed important edible fish. This has the potential to reduce the long-term utilizable productivity of coral reef fisheries. Another concern is that urchins may erode the fringing reef which is the shores protective barrier. The loss of the fringing reef could increase beach erosion and endanger economic investments along these beaches.

In order to avoid these environmental problems it is essential to manage inshore coral reef fisheries and especially sea urchin predators. A general management strategy for inshore fisheries needs to be developed and implemented although the details require further research in order to insure intelligent decisions. Sea urchin predators include a mixture of species. Some species such as parrotfish are a valuable food source, the Bullmouth helmet shell (Cypraecassis rufa) and porcupine fish are sold for their ornamental value and the Boxstar (Culcita chnudeliana) has no commercial value. Triggerfish, which are probably the most important sea urchin predators, are reputed to be poisonous but they are commonly eaten in Kenya once their skins are removed. It is important to determine the importance of some of these species as effective sea urchin predators and their economic value in order to place restrictions on harvesting of those species which have the greatest predation ability but the least economic or food value. Some species should receive protection or harvesting quotas. The potential long-term loss of coral reef fisheries productivity justifies the implementation of restrictions.

Tourism at the coast is as it is in the rest of Kenya; a two edged sword. The construction of large hotel complexes puts a strain on the reef as it supplies fish and shell products for tourists, hotel staff and associated workers. This constant demand created by tourism may eventually self-limit itself if the reef is eroded by sea urchins and beaches erode due to increased currents and waves. On the other hand, it is because of tourism that we have Kenya's beautiful marine parks. The park's are areas of high fish, shell and coral diversity which acts as refuge for many species which are threatened by overfishing and subsequent changes in the coral reef's flora and fauna. One way to resolve this conflict is to keep tourists and marine parks close together. The Malindi-Watamu Park and Reserve is an excellent example of a well planned marine reserve as it offers tourists easy access to Parks, which have the richest fauna, while maintaining the lower diversity reserve as a buffer and corridor between parks. South coasts Diani Beach which is the most populated tourist beach in Kenya has no park nearby and is the most over-exploited reef in Kenya. Kisite-Mpunguti Park is too removed for easy access and from the problems created by overfishing. We have therefore suggested that the status of Diani Beach be changed to a protected area. Diani's fisheries productivity is presently so low that it would create a greater economic benefit to the country as a Park Reserve. Beyond the government revenue from entrance fees it would create additional tourism related jobs to replace lost fisheries jobs.

In order to increase fisheries production, Kenya is increasingly turning to offshore fisheries or aquaculture production. Both of these require larger capital investments and running costs than inshore fishing and therefore the net benefits may be less than inshore fisheries and less accessible to local fishermen.

Additionally, low Kenyan fish prices may make these alternatives less profitable. To be profitabale it is necessary to culture luxury foods for tourist consumption or export in order to benefit from world market prices. If fisheries products are easily exported than the local market will have to compete with the world market resulting in an inflation of local fish prices or the consumption of fish products not sold on the world market. Although, this may generate foreign exchange it is questionable who benefits in the long-term especially if the stated intention is to increase food production for local consumption. Certainly Kenya's small scale fishermen cannot afford this type of investment nor can they develop the export market, nor will Kenyans enjoy the products without significant price increases. It may be best to keep these alternatives as means of generating foreign exchange through sale to tourists or exportation but such projects should not be justified as a means to increase local food production and consumption. This suggests that inshore fisheries will continue to be an important food source for local consumption and therefore their management is critical for maximum long-term production.

Kenya's fisheries are at a critical point when serious planning and management are needed in order to cope with future changes. Kenya's increasing population and coastal tourism will continue to create increasing demands on local fisheries. This demand combined with unregulated fishing will ultimately lead to overexploitation, a collapse of many fisheries resources and associated environmental problems. Intelligent policy and management decisions implemented now will be far more effective and less expensive in maintaining fisheries productivity than rectifying future environmental problems and losses in fisheries productivity. Reliance on offshore fisheries and aquaculture to supply the future demand although necessary is an overly optimistic solution and cannot be used as an oversight for the lack of inshore fisheries management. Inshore areas presently provide the bulk of coastal fisheries production and will continue to do so if management is implemented to insure their long-term productivity.

11.2. CHANGES IN PATTERNS OF FAUNAL DISTRIBUTION IN MANGROVE ECOSYSTEMS AT THE KENYAN COAST DUE TO NATURAL AND UNNATURAL CAUSES

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ABSTRACT

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Faunal distribution in mangrove ecosystems in Kenya were for the first time described. As in other areas of the Western Indian Ocean the faunal distribution were influenced by a combination of natural factors like texture of sediments, shade, shore level, ground watertable and biological interactions. It was also noted that under shade conditions species diversity is higher. Sediment wise, the species diversity increase with the following order of changes in sediment textures: sandy, sandy mud, muddy sand and muddy substrates. The latter substrates remain wet or soggy because the ground watertable is close to the surface of the shore allowing the groundwater to seep through to the surface. It was significantly found out that unnatural modification of the microenvironment in the mangrove biotopes due to exploitation and removal of the mangroves, excavation of prawn ponds affect faunal distribution.

At the upper shore levels where the bare salty areas or *inversa* flats in the mangrove forests occur, only *Uca inversa* which was the most abundant organism and few *Cerithedia decollata* which around mid-day rested by means of mucus threads on the pneumatophores of adjacent stunted shrubs of *Avicennia marina* were found. The muddy sand prawn ponds dug in the *inversa* flats and the channels bringing seawater to the ponds supported various mangrove creek edge fauna in addition to the *Uca inversa*. Thus the excavation in these bare salty flats made way for higher species diversity.

Signs that show that excessive cutting of mangroves which alter shade conditions and may directly or indirectly encourage transport of sand from the sand dunes to the muddy sand areas thereby making them sandy mud habitats and subsequently causing changes in faunal distribution were observed. It was observed that in muddy sand habitats with predominantly *Ceriops tagal* mangroves, there were numerous *Sesarma guttatum* and scanty *Uca lactea* and *U. gaimardi* but at similar areas where these mangroves were heavily cut and substrate being sandy mud, *Uca lactea* was the only *Uca* spp present and *Sesarma guttatum* was scanty. In more openish areas there was luxuriant lateral growth of *Sesuvium portulacastrum* among the *Ceriops tagal* which is an unusual occurrence because it grows among the *Avicennia marina* stands at the higher shore.